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ALTO MAIPO HYDROELECTRIC PROJECT

BASIC ENGINEERING

CONTRACT AM-CO304

EL YESO INTAKE AND EMERGENCY WEIR HYDRAULIC CALCULATION REPORT

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							N°: 610-CI-MCA-005	

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1. INTRODUCTION

The following calculation report comprises the design, at a Basic Engineering level, of the El Yeso intake and of the lateral emergency weir of Alfalfal II power plant.

In general terms, the water intake considers a front barrier with a lateral intake followed by a Parshall flume, discharging the waters collected to the El Yeso head tunnel. Immediately downstream from the flume, a discharge lateral weir to Yeso river is considered, in case of a stoppage of the Alfalfal II power plant.

It is worth mentioning, that in order to maximize the generation height of Alfalfal II power plant, it is considered to locate the intake of El Yeso at the highest elevation possible, without influencing the existing flume upstream of the river and which is property of Aguas Andinas S.A.

Figure 1.1 shows the general location of El Yeso intake and of the existing flume upstream from the considered collection point.

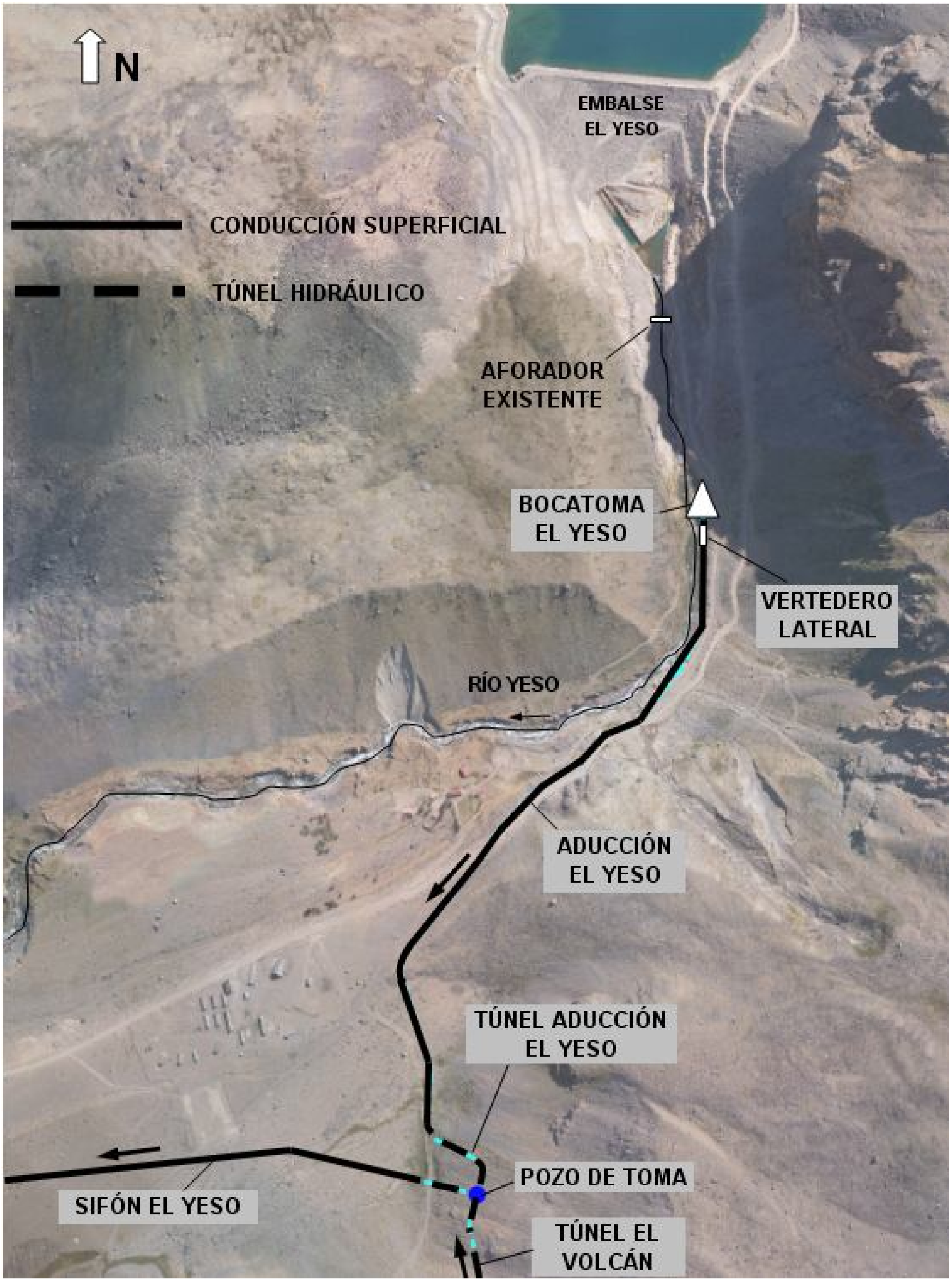


Figure 1.1: General Location of the El Yeso Intake and the Existing Flume

2. INFORMATION

The following information has been used for creating this Calculation Summary:

1. "Formulaire des Conduites Forcées Oléoducs et Conduits D'aération". L. Levin (1968)
2. "Hidráulica Aplicada al Diseño de Obras" (Hydraulics Applied to Works Designing.) H. Mery (2005)
3. "Barrages Mobiles et Ouvrages de Derivation ». Maurice Bouvard (1984)
4. "Canals and Related Structures". United States Department of the Interior. Bureau of Reclamation. (1967)
5. "Embalse El Yeso – Llenado Controlado" (El Yeso Reservoir - Controlled Filling) Dirección de Riego (1984) (Watering Department)
6. Intake in Olivares river. Alfalfal Power Plant. AES GENER
7. "Water Measurement Manual". Bureau of Reclamation (2001)
8. "Hidraulica" (Hydraulics). Francisco Javier Domínguez (1974)
9. "Hydraulic Design of Stilling Basins and Energy Dissipators". Engineering Monograph Nº 25. U.S. Bureau of Reclamation (1978)

3. CALCULATION BASIS

3.1 Design Flows

The design flows for the El Yeso intake, are shown in Table 3.1.

Table 3.1: Design Flow of El Yeso Intake and Lateral Weir

Stream Intake	Q_{COLINA} (m^3/s)
Maximum flow of the intake (design)	15.0
Environmental Flow	0.46
Flow of the Lateral Weir	27.8
Flow Increase	80.0

It is worth mentioning that the flow considered for the increase was obtained from the maximum operational flow delivery recommended by the study carried out by the former Watering Department. That study shows that for values over 80 m^3/s, there are disturbances observed over the bridge of El Yeso river and over the slope of the access road to the wall.

The maximum flow mentioned is known by Aguas Andinas, so, the operation of El Yeso reservoir is conditioned by this evacuation flow limit.

3.2 Front Barrier

The front wall has been considered to be made of reinforced concrete. The crest elevation has been adopted with a minimum of 2 m. from the level of the flow's bed.

The water level over the wall under flow increase conditions has been estimated through the evacuation of weir expense given by the following expression:

$$Q = mLh\sqrt{2gh} \quad (1)$$

where **L** is the length is the length of the threshold in m., **h** is the load on the threshold of the weir in m., and **m** is the expense coefficient. An **m**=0.42 coefficient has been considered.

The crest height of the barrier has been adopted in at least 0.5 m over the maximum water level in the lateral intake.

3.3 Lateral Intake

A grating chamber is considered in the lateral intake area, with the aim of avoiding the entrance of leaves, branches and other unwanted objects. For the calculation of loses in the grating, the Berizinski (1958) expression has been used, according to the recommendations of Levine and Mery. The equations used are given by the relationships (2), (3) and (4).

$$\Lambda_R = \zeta \times \frac{V^2}{2g} \quad (2)$$

$$\zeta = K_d \times K_f \times p^{1,6} \times f\left(\frac{L}{b}\right) \times sen\theta \quad (3)$$

$$f\left(\frac{L}{b}\right) = 8 + 2,3\frac{L}{b} + 2,4\frac{b}{L} \quad (4)$$

where Λ_R is the loss of load in m., ζ the total singular coefficient loss of the grating, K_d is a coefficient that depends on the cleaning system according to the figures mentioned in Table 3.2, K_f a coefficient that depends on the shape of the bars according to the recommended values in Table 3.3, **p** the relationship between the surface covered by the bars and the total surface (gross) of the grating (in general 22to 38%), **L** the length of the bars in the direction of the flow, **b** the spacing between the bars, θ the dihedral angle that forms the grating with the horizontal (in general 65 to 90º) and **V** the speed through the grading m/s.

Table 3.2: Recommended Values for the Cleaning Coefficient K_d

CLEANING TYPE	K_d
Automatic	1.1 – 1.2
Old System	1.5
Manual	2 - 4

Table 3.3: Recommended Values for Shape Coefficient K_f

BAR TYPE	K_f
Long, Rectangular	0.51
Circular Section	0.35
Rectangular with Circular Edges	0.32

The gross runoff rate has been limited to a maximum value of 0.5 m/s in the section immediately downstream from the grating, according to Bouvard's recommendation. This value avoids for the material to be firmly stagnated in the bars, allowing for manual cleaning.

The separation between bars has been set in 7 cm, with a bar thickness of 1 cm. and a bar length (in the sense of the flow) of 10 cm.

3.4 Environmental Flow Delivery Works

In the slide gate of the sluice the location of an orifice is considered for the delivery of the environmental flow to Yeso river.

The diameter of the orifice has been determined from the equation of the following:

$$Q = C \cdot A \cdot \sqrt{2g \cdot h} \quad (5)$$

where **Q** is the flow in m^3/s, **C** = 0.61 the contraction coefficient, **A** the area of the orifice in m^2 and **h** the load over the center of the orifice in m.

3.5 Parshall Flume

The dimensioning of the Parshall flume has been carried out following the recommendations of the "Water Measurement Manual."

The elevation of the invert of the El Yeso headrace, in the discharge of the flume, has been established adopting a maximum recommended submergence of 80%. In this way it is assured that, for the width of a chosen flume, the flow will only depend on the runoff height in the measurement section, located immediately upstream from the contraction of the flume.

3.6 Sluice Gates

There are two sluice channels considered, and each one is equipped with a radial gate. The channel next to the grating will discharge the finer sediment, while the channel closer to the wall will discharge thick sediment.

The gates have been designed so as to allow the generation of an aggressive torrent that can allow the entrainment of material, due to which the dimensions of the sluice channels have been adopted in such a way that the critical height is lower to the available height after opening the sluice gates.

The sluice system adopted is based on the design of the Olivares intake of the Alfalfal power station, which has shown a satisfactory performance. It must be pointed out that the design of that water intake, both for intake as for flow increase, are very similar to the case of the Río Yeso collection.

3.7 Threshold Elevation of the Lateral Intake of the Channel

A 2 m minimum elevation of the threshold of the lateral intake channel over the level of the bottom of the flow has been adopted, in order to provide an adequate volume for the accumulation of sediments at the bottom of the intake.

3.8 Lateral Weir and Gradually Varying Channel

To determine the load over the lateral weir located immediately downstream from the Parshall flume, the following weir equation is considered:

$$Q = mLh^{3/2}\sqrt{2g} \qquad 6$$

Where **L** is the length of the threshold in m, **h** is the load in m, **Q** is the flow in m^3/s and m is the discharge coefficient. For this case, considering the fact that the weir is of lateral type, but that it works in a meeting point of two flows in the opposite direction (the one collected in the water intake and the one coming from the El Volcán tunnel), a value of **m** = 0.35 has been adapted, according to the recommendation written in the text of F.J. Domínguez.

The gradually varying channel located at the discharge of the lateral weir, has been calculated according to the procedure described in “Hidráulica Aplicada” (Applied Hydraulics) of Francisco Javier Domínguez. The main characteristics of the design are the following:

- Set runoff heights above the critical in the stretch located upstream from the final downstream section (so as to prevent considerable superficial undulations)
- Height in the downstream section controlled by a grade line at the beginning of the baffle blocks drop structure that discharges to Yeso river
- Slope of the bottom of the gradually varying channel i = 1.5%

The details of the calculation procedure are shown in Annex B.

3.9 Baffle Blocks Drop Structure (Discharge Works)

For the dimensioning of the baffle blocks drop structure located at the discharge of the gradually varying channel, the recommendation designs of the U.S. Bureau of Reclamation “Hydraulic Design of Stilling Basins and Energy Dissipators” (Engineering Monograph Nº 25, 1978) were adopted.

The main considerations are the following, where **W** is the width of the drop channel in feet, **Q** is the design flow in feet^3/s, **H** is the height of the baffle block, $\mathbf{h_C}$ the critical height considering the width of the adopted channel,

- Minimum width of the drop channel ($\mathbf{W_M}$) : $\mathbf{W_M} = \mathbf{Q}/60$
- Recommended width of the channel ($\mathbf{W_R}$) : $\mathbf{W_R} = \mathbf{Q}/20$
- Recommended height of the baffle block (**H**) : $\mathbf{H} = 0.9\ \mathbf{h_C}$
- Minimum width of the baffle block ($\mathbf{b_M}$) : $\mathbf{b_M} = \mathbf{H}$
- Recommended width of the baffle block ($\mathbf{b_R}$) : $\mathbf{b_R} = 1.5 \times \mathbf{H}$
- Clearance between lines : min {1.8 m ; 2 x **H**}
- Maximum slope of the channel : 2:1 (H:V)

Figure 3.1 shows the type of drop considered.

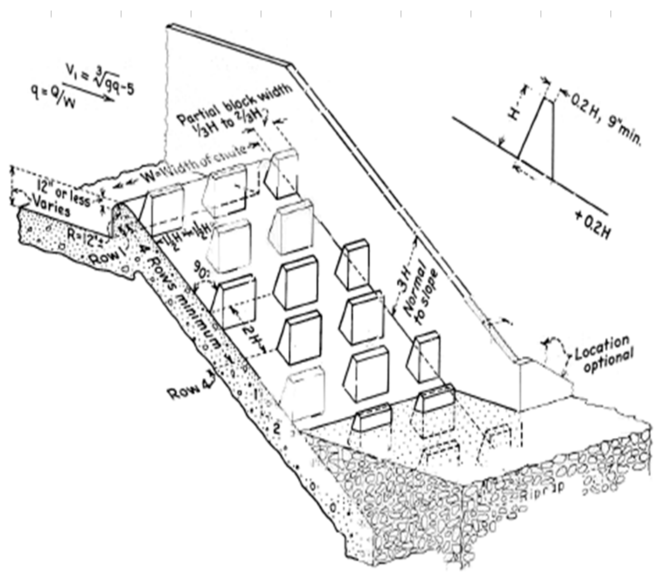


Figure 3.1: Baffle block drop structure according to USBR

4. DETERMINATION OF THE MAXIMUM LEVEL OF WATERS IN THE COLLECTION

4.1 General Aspects

The maximum allowable level of waters in the collection area has been estimated as one that does not affect the operation of the flume located upstream from the flow of Yeso river, which is shown in Figures 4.1 and 4.2.

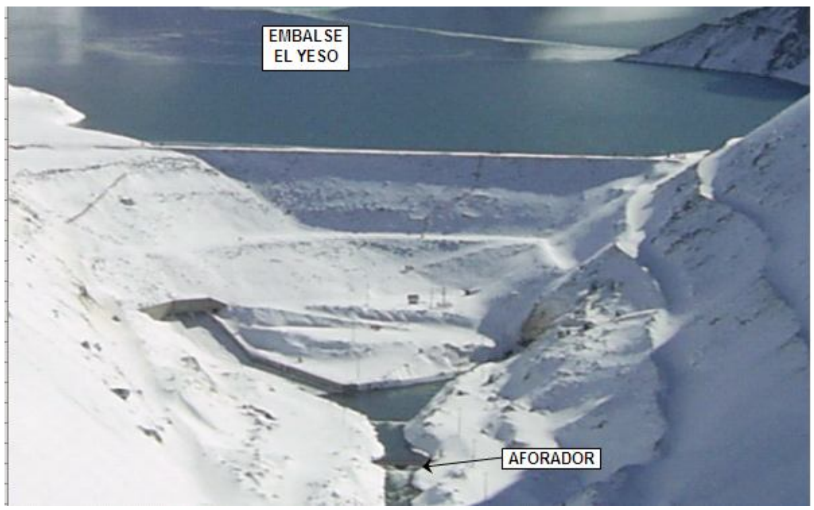


Figure 4.1: Flume in Yeso River – Aerial view from the downstream area

Figure 4.2: Flume in Yeso River – Aerial view from the upstream area

4.2 Determination of the Maximum Level of Waters on the El Yeso Water Intake

The maximum level of waters in the El Yeso water intake should not influence the weir located downstream from the reservoir, considering the most unfavorable situation that corresponds to an increase condition of 80 m^3/s and with the El Yeso water intake out of service. Such level has been determined by analyzing the longitudinal profile of the bottom of the flow, which is shown in Figure 4.3.

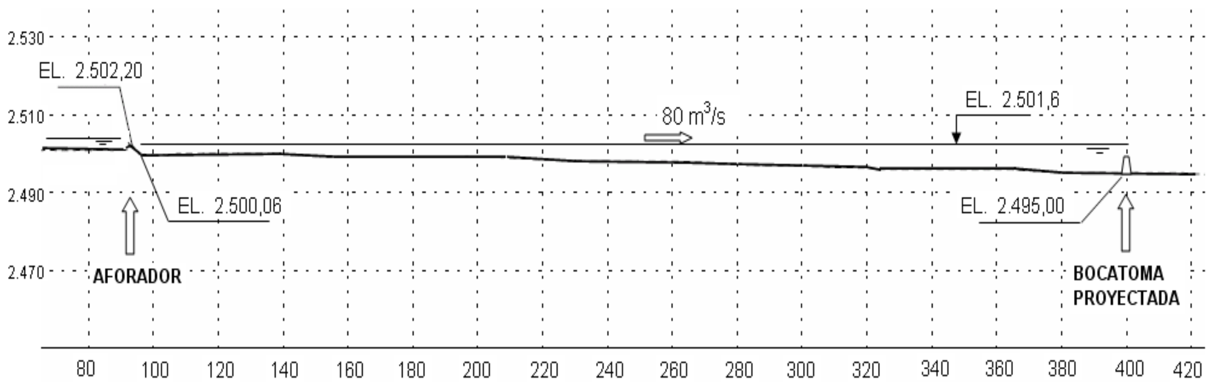


Figure 4.3: Longitudinal Profile of Yeso River

Figure 4.3 shows that the maximum allowable level of waters in an increase condition, in the wall of the El Yeso intake corresponds to the elevation of 2,501.6 m.a.s.l., since the altitude of the threshold of the flume of the river is located at an elevation of 2,502.2 ma.s.l. There is a 60 cm clearance.

For a flow of 80 m^3/s, the load over the weir on the El Yeso intake reaches an approximate value of 1.8 m, due to which, the maximum elevation of the threshold of the front weir of the intake reaches an elevation of 2,501.6 – 1.8 = 2,499.8 m.a.s.l. In this way, the maximum allowable elevation for the water level in the grating of the intake, considering a flow of 15 m^3/s, has been adopted to the elevation of 2,499.5 m.a.s.l., considering a compensation of 30 cm regarding the threshold of the front wall.

5. DIMENSIONING OF THE WORKS

5.1 Front Barrier of the Intake in an Increase Condition

For the 80 m^3/s flow increase, the load associated to the front barrier given by equation (1), is shown in Table 5.1.

Table 5.1: Load over the Front Barrier on the Streams of El Yeso Intake

PARAMETER	UNIT	VALUE
Flow increase	(m^3/s)	80.0
Wall width	m	17.3
Load on the threshold	m	1.8
Maximum Load Elevation on the Threshold	m.a.s.l.	2,501.6

5.2 Lateral Collection

The works that comprise the lateral collection are those shown in Figure 5.1.

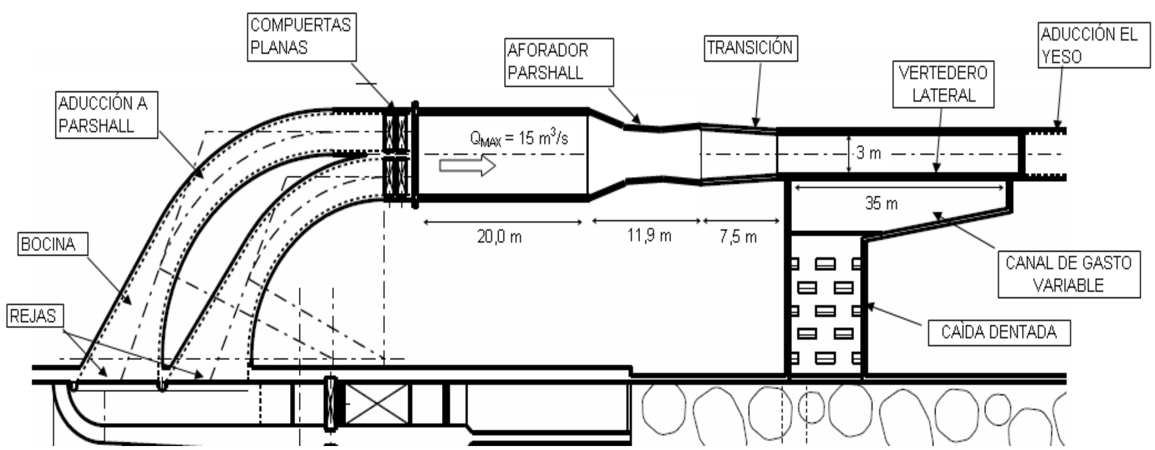


Figure 5.1: Lateral Collection Works of El Yeso Water Intake

The dimensioning of the works that comprise the lateral collection of the El Yeso water intake, has been carried out from downstream, that is to say, calculating the hydraulic axis starting from the beginning of the El Yeso headrace and finishing in the grading area of the water intake.

It must be said that the El Yeso headrace is made of a reinforced concrete duct with a square section of 2.8 x 2.8 m that has a length of 367 m, followed by a circular concrete duct with a diameter of D = 3.1 m and a length of 956 m, which is followed by 14m^2 concrete lined tunnel lined of 126 m length, which is finally discharged into the Intake Well.

5.2.1 Parshall Flume and Transition to the El Yeso Headrace

For a flow with a design of 15 m^3/s, a Parshall flume has been selected, this has a contraction width of **W** = 15 feet (4.57 m) and a total length of $\mathbf{L_T}$ = 11.9 m.

Downstream from the flume there is a transition to the El Yeso headrace considered, from a width of 5.59 m (corresponding to the area downstream from the flume) at 2.8 m (corresponding to the width of the first stretch of the headrace.) Adopting a transition length of 7.5 m there is a wall deflection angle of 10.5º, very close to the value of 10º that is usually recommended.

The flume has been designed so that the elevation difference between the invert in the contraction of the drain pipe and the invert at the exit is of 1.51 m, which ensures an 80% submergence for the design flow, according to the recommendations of the Bureau of Reclamation.

The details of the Parshall flume's design are shown in Annex A of this report. Figure 5.2 shows a cutaway with the main dimensions and the hydraulic profile for a maximum flow of 15 m^3/s.

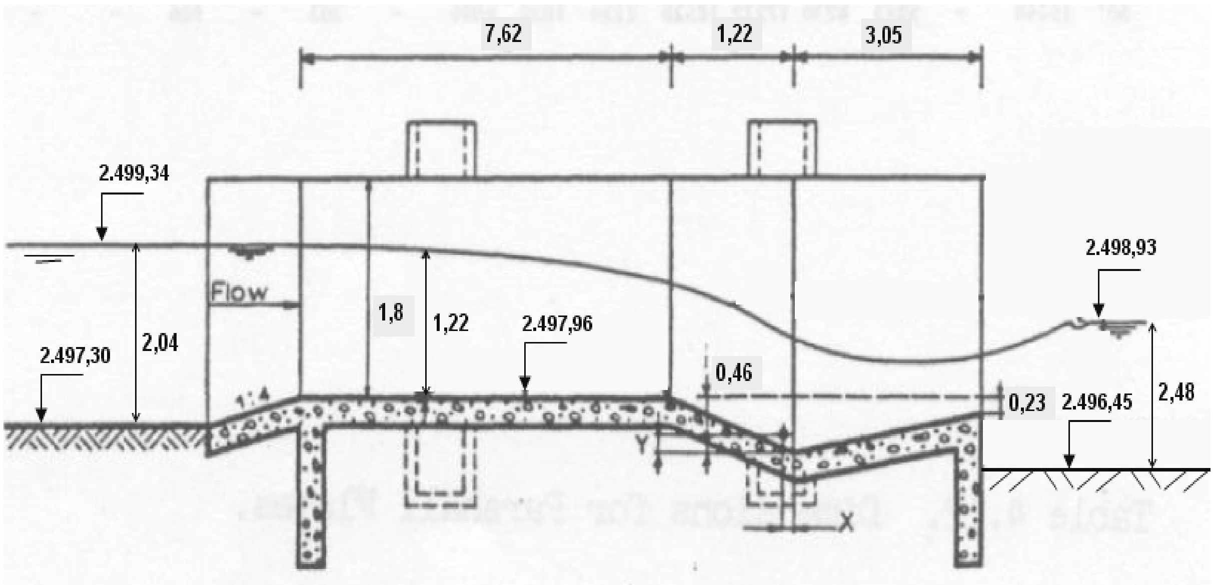


Figure 5.2: Parshall Drain Pipe Profile

5.2.2 Headrace to the Flume

The headrace to the flume is comprised by two horns which confluence in a 7.6 m channel located immediately upstream from the Parshall drain pipe. The later has a 20 m length, which allows having an even flow before going into the drain pipe.

The water levels in the headrace of the flume have been estimated through the calculation of the hydraulic axis, adopting as a condition for the edges downstream the level of the runoff at the beginning of the Parshall drain pipe that has a value of 2.04 m (see Figure 5.2, which corresponds to the 2,497.3 elevation (invert) + 2.04 = 2.499.34 m.a.s.l.

After carrying out the calculation of the hydraulic axis, the runoff heights have been determined in the cross-sections shown in Figure 5.3.

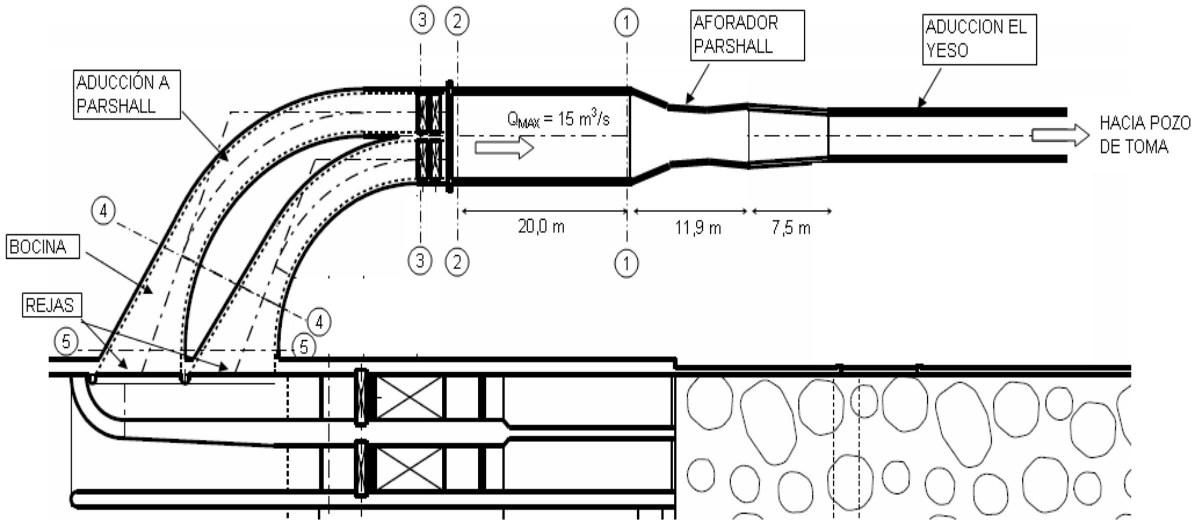


Figure 5.3: Cross-sections of the Hydraulic Axis Calculation for the Headrace to the Flume

The runoff heights are those shown in Table 5.2:

Table 5.2: Calculation of the Hydraulic Axis for the Headrace to the Flume

SECTION	LOCATION	h (m)	h m.a.s.l.
1-1	Parshall - start	2.04	2,499.34
2-2	Beginning of the single channel	2.04	2,499.34
3-3	End of separate channels	2.08	2,499.38
4-4	End - horns / Beginning - separate channels	2.05	2,499.40
5-5	Beginning - horns downstream from grating	2.12	2,499.49

5.2.3 Gratings

There are two grating areas of 7.0 m width and 2.2 m height considered. Applying the load loss criteria set forth in 3.3 a loss of the order of 1 cm is obtained for the design flow.

In order to allow for the manual removal of sediments trapped in the grating, there has been a maximum gross rate of 0.5 m/s set in the grating area. In fact, since the height of the waters in the grating area is 2.13 m (considering 1 cm as the loss in the grating); the runoff area reaches a value of 2.13 x 7 = 14.91 m^2. The gross rate is then:

$$V_{GROSS} = Q/A = 7.5/14.91 \approx 0.5 \text{ m/s}.$$

5.3 Sluice Gates

There are two sluice gates considered for the intake. The gates have been designed so that together they can evacuate the entire design flow, in case there is the need to carry out maintenance works in the lateral intake works.

The width of the sluice gates and channels has been determined so that the critical height in the channels is equivalent to half of the runoff height, as a maximum, available in the gate area, established in 2 m.

Adopting a 3 m width for the channel, and 50% of the design flow running off through each gate section, there is a critical height of 0.86 m, which corresponds to 43% of the available height on the gate section. In this way, there are two 3 x 2 m sluice gates of hydraulic section considered.

It is worth mentioning that the gross depth for the accumulation of sediments immediately upstream from the sluice gates is of 2.07 m.

5.4 Environmental Flow Delivery Works

The delivery works of the environmental flow corresponds to a drilled orifice in the plate of the eastern radial gate. Its diameter and location have been adopted so as to deliver 460 l/s to Yeso river when the water level on the intake works matches exactly that of the lateral collection invert. In this way, whenever there is a flow lower than or equal to 460 l/s in the river, the intake will not collect water.

The design is shown in Table 5.3, where $\mathbf{D_{ORIF}}$ is the diameter of the orifice that will be located in the sluice gate, $\mathbf{h_{ORIF}}$ is the distance or depth of the axis of the orifice to the invert level of the lateral intake or hydraulic load, $\mathbf{h_{MAX}}$ is the maximum load for the design flow compared to the axis of the orifice, and $\mathbf{Q_{MAX}}$ is the maximum flow associated to $\mathbf{h_{MAX}}$ that discharges through the orifice to each stream. The orifice has been designed with the minimum depth criteria between the bottom of the collection and the axis of the orifice of the order of 1.0 m. The previous variables are show in Figure 5.4.

Table 5.3: Environmental Flow Delivery Works

FLOW	Q_{ENVIR} (m^3/s)	D_{ORIF} (mm)	h_{ORIF} (m)	h_{MAX} (m)	Q max (m^3/s)
Yeso river	0.460	450	1.14	3.22	0.77

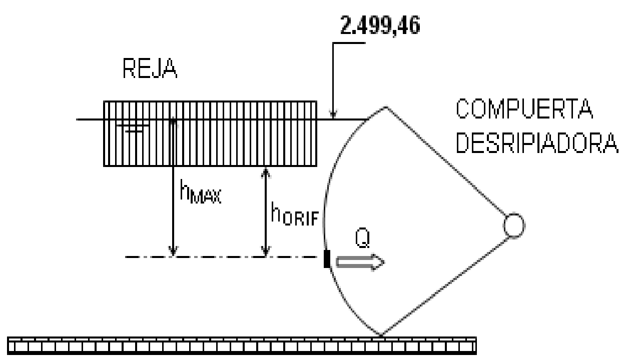


Figure 5.4: Location of the Environmental Flow Delivery Orifice

Table 5.3 shows that the orifice delivers 310 l/s more than the value required for the maximum load associated to the design flow of 15 m^3/s.

5.5 Lateral Weir

An emergency discharge to Yeso river is considered, and it consists of a lateral weir located immediately downstream from the Parshall flume. The purpose of this is to allow discharging the flow resulting from the sum of the contribution from the El Volcán tunnel and El Yeso water intake, in case of a stoppage at the power plant.

The maximum instant flow required to evacuate in case of a turbine stoppage is 15 + 12.8 = 27.8 m^3/s (Yeso + Volcán).

The flow discharge to Yeso river takes place in two areas: The first corresponds to the lateral weir, while the second one corresponds to the front weir of the El Yeso water intake. This is due to the backflow effect of the hydraulic axis, where this exceeds the height of the weir's threshold of the front barrier of the intake. This double discharge has the advantage of relieving the design flow of the lateral weir in 8% and reducing in some centimeters the maximum level of the hydraulic axis in case of a stoppage of the power station. In any case, most of the flow (25.6 m^3/s) is discharged by the lateral weir, as it is shown in Figure 5.5.

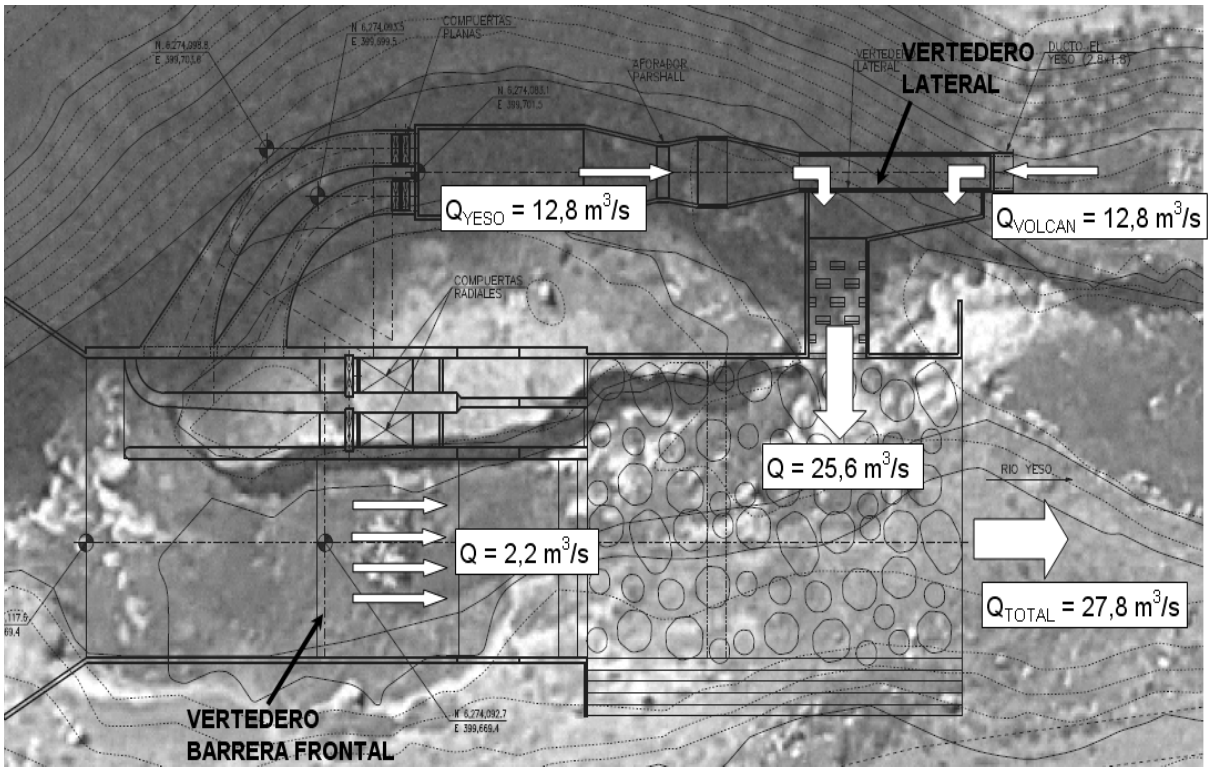


Figure 5.5: Discharge to Yeso river for a Stopped Power Station – Maximum Flow Q = 27.8 m^3/s

The hydraulic calculation for both weirs is shown in Table 5.4.

Table 5.4: Discharge to Yeso River with a Stopped Power Plant and with a Maximum Flow (27.8 m^3/s)

DISCHARGE POINT	FLOW (m^3/s)	LOAD ON THE THRESHOLD (m)	MAXIMUM ELEVATION m.a.s.l.
Lateral Weir	25.6	0.61	2,499.61
Front Barrier	2.2	0.17	2,499.97
TOTAL (m^3/s)	27.8		

These values correspond to a lateral weir with a 35 m threshold length and a discharge coefficient of **m** = 0.35. For the front weir, a length of 17.3 m and a coefficient of **m** = 0.42 has been adopted, as it was shown in item 5.1.

It must be said that the threshold of the lateral weir is located 33 cm over the maximum water level in the El Yeso headrace for a permanent regime and 3 cm over the corresponding energy level, as it is shown in Figure 5.6.

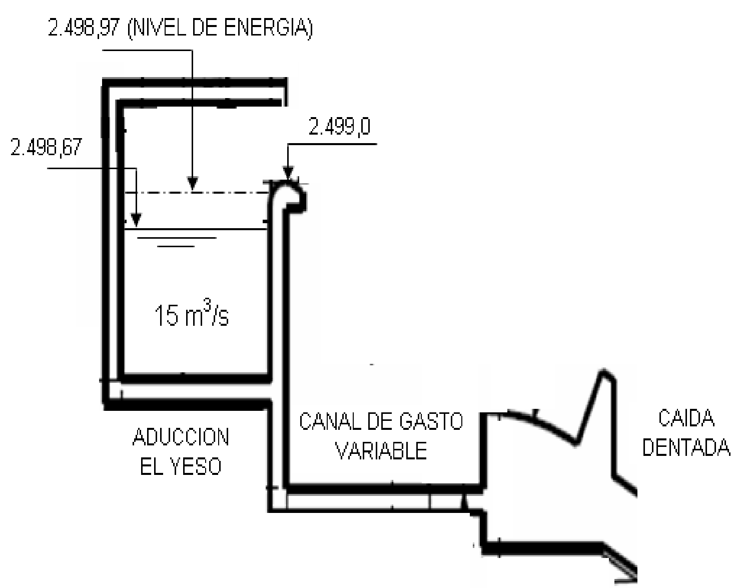


Figure 5.6: Weir Threshold Compared to Hydraulic Levels in the El Yeso Headrace

The discharge weir on a 1 m depth dead water zone, followed by a baffle blocks drop. The entire profile of the emergency works is shown in Figure 5.7.

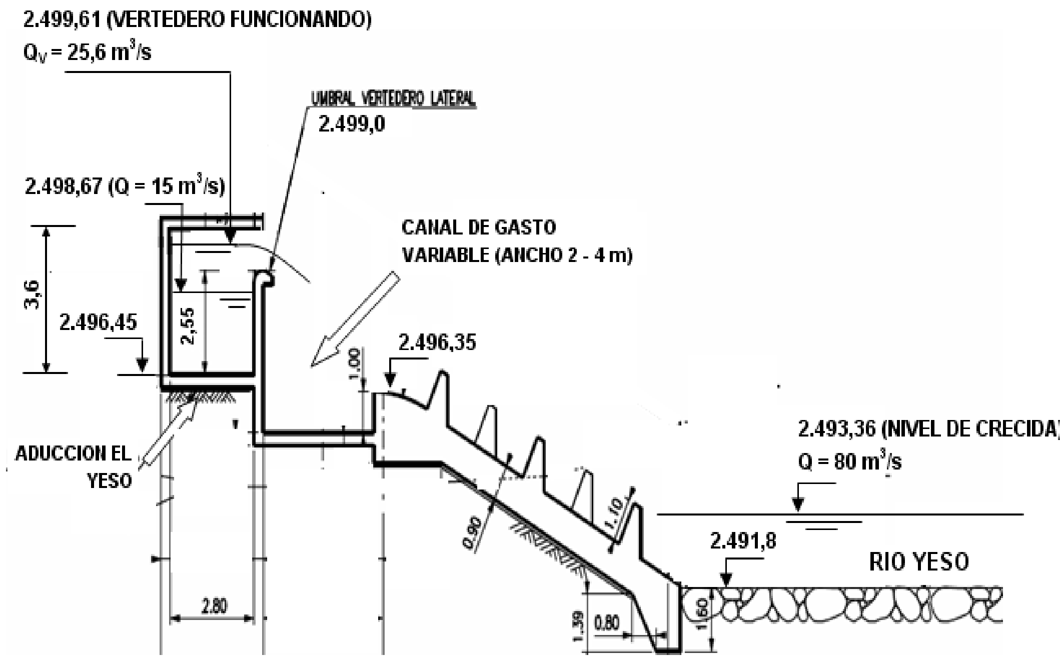


Figure 5.7 Profile of the Discharge Weir to Yeso River

5.6 Gradually Varying Channel

A gradually varying channel is the one that receives the discharge of the lateral weir designed in the previous paragraph. The channel considers a variable width of 2 m at the upstream end, and 4 m at the downstream end. The bottom slope in the runoff direction is 1.5%.

The hydraulic verification details for a 25.6 m^3/s flow are shown in Annex B of this calculation report. Figure 5.7 shows the hydraulic profiling calculated for that structure.

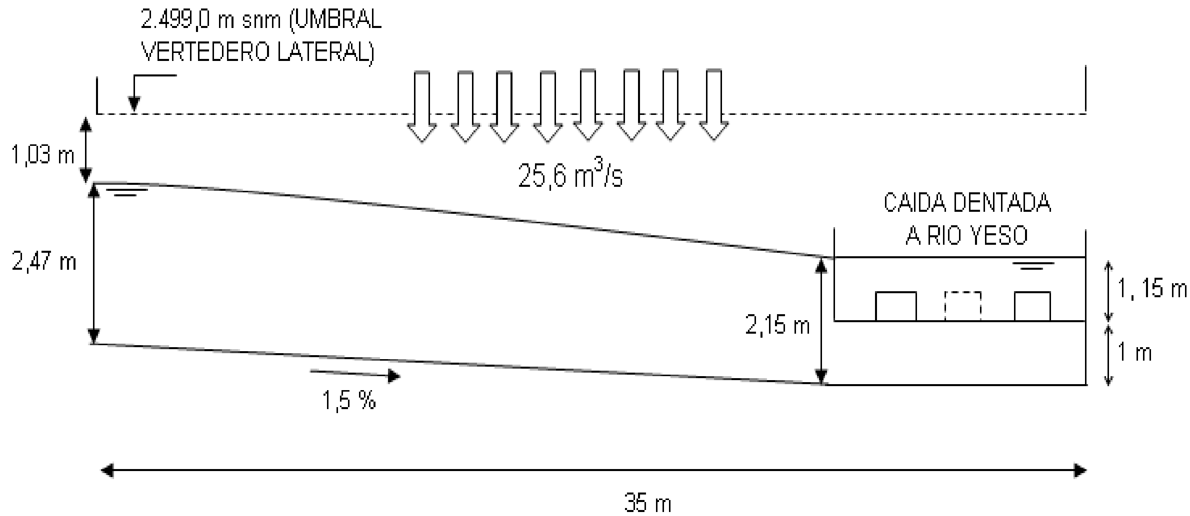


Figure 5.7: Hydraulic Profiling of the Gradually Varying Channel

5.7 Baffle Blocks Drop Structure

Applying the criteria described on item 3.10, the dimensioning shown in Table 5.5. is obtained.

Table 5.5: Baffle Blocks Drop Structure Dimensioning

PARAMETER	VALUE	UNIT
Design Flow	25.6	(m^3/s)
Drop Gross Height	4.55	m
Width	6.0	m
Baffle Blocks Height	1.1	m
Cross-sectional clearance between baffle blocks	1.1	m
Longitudinal Clearance between Baffle Blocks	2.2	m
Baffle Blocks Width	1.1	m
Walls Heights	3.3	m

The details of the baffle blocks drop structure are shown in plan views Nº 610-CI-PLA-066 and 067.

5.8 Hydraulic Profiling of Yeso Water Intake

A hydraulic profiling for El Yeso water intake is described for two scenarios. The first (Figure 5.8) corresponds to the maximum flow for the power station under operation, while the second one (Figure 5.9) corresponds to a maximum flow for the power station under a stoppage condition.

It must be pointed out that the water heights are shown in bold, while the energy level is shown in parenthesis.

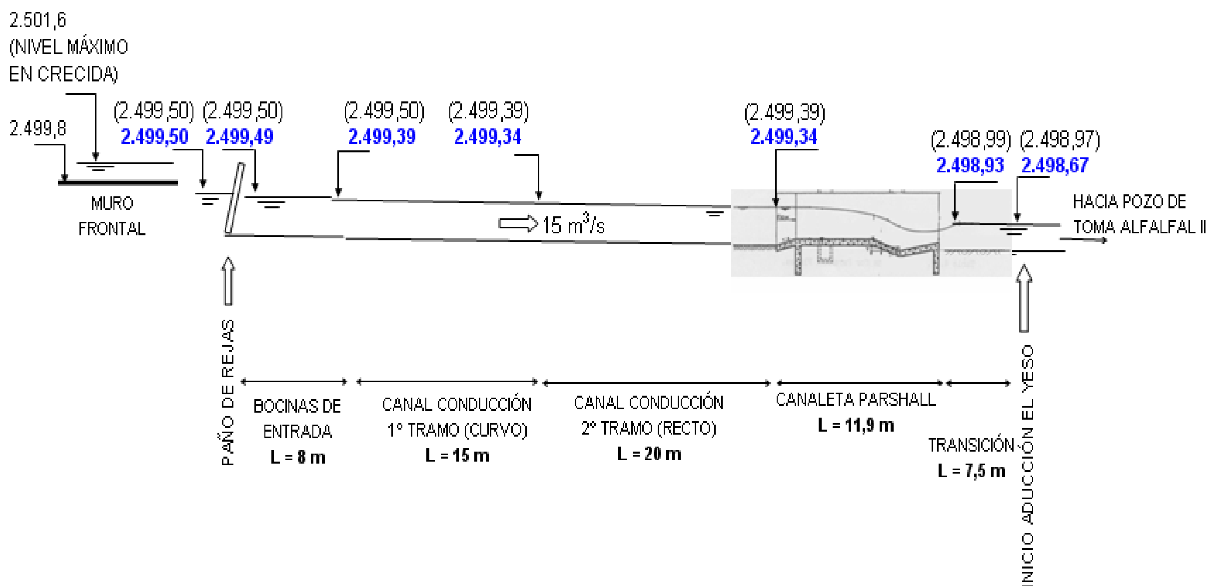


Figure 5.8: Hydraulic Profiling of El Yeso Intake Q = 15 m^3/s – Power Station Under Operation

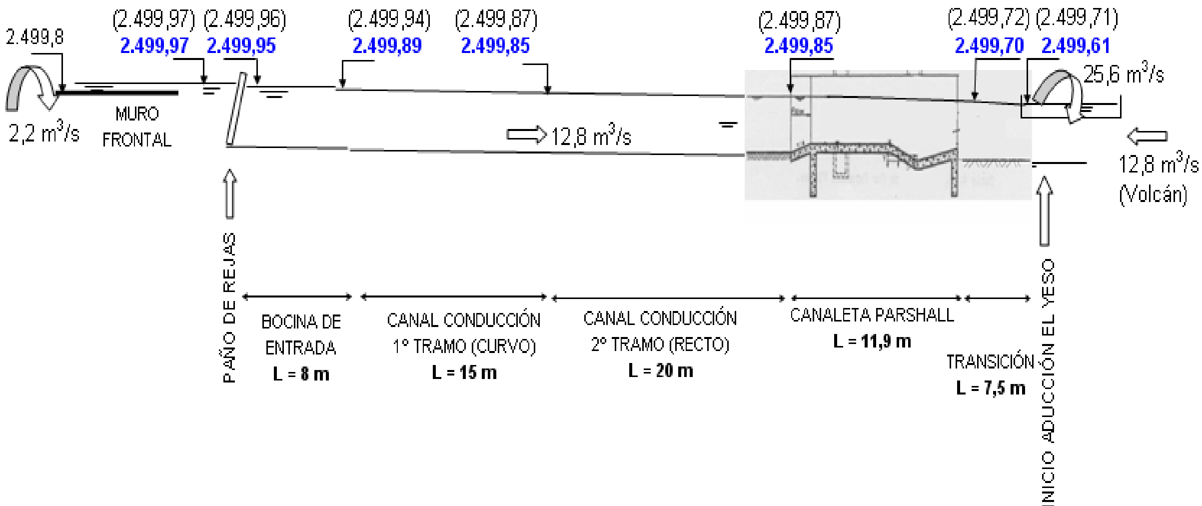


Figure 5.9: Hydraulic Profiling of El Yeso Intake Q = 12 m8/s – Power Station Under a Stoppage Condition

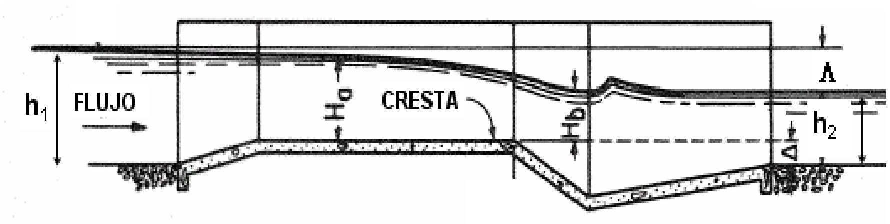
ANNEX A

DIMENSIONING OF THE PARSHALL FLUME

DATOS:

Q_{MAX} (m^3/s) = 15

CALCULOS:



1. Altura Escurrimiento Aguas Abajo (h_2)
   Corresponde a la altura de escurrimiento al inicio de la transición

h_2 (m) = 2,48

2. Ancho de Contracción (W)

Q_{MAX} (m^3/s)= 15 ⟹ W_{TEOR} (m) = 4,57

Ancho Adoptado:	W (ft) =	15,0
	W (m) =	4,57

3. Sumergencia Máxima (H_b/H_a)

H_b/H_a <= 0,8

4. Altura Escurrimiento Sección de Aguas Arriba (H_a)

$$Q = C \times H_a^n$$ Q: cfs ; H: ft

W (m) =	4,57	⇨	C =	57,81
			n =	1,6

H_a (m) = 1,22

5. Altura de Escurrimiento Máxima Admisible (H_b)

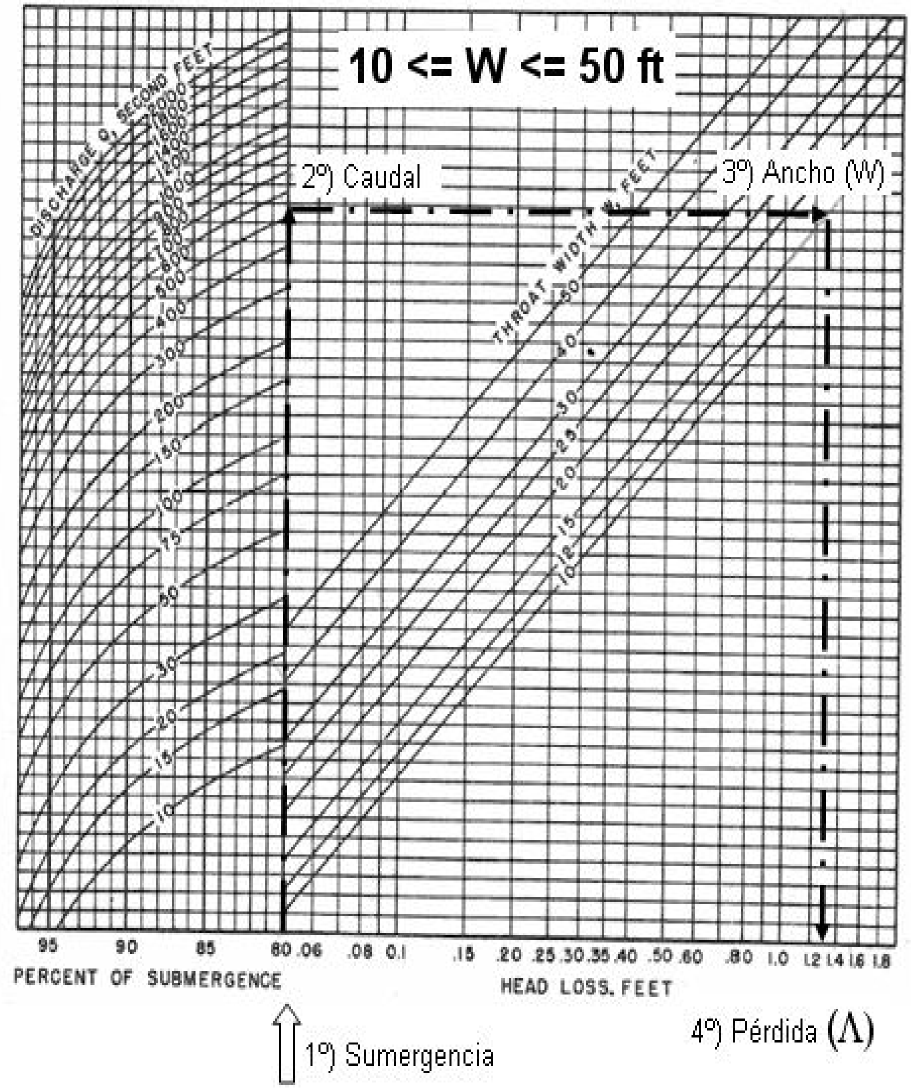
H_b (m) = 0,97

6. Altura entre Cresta y Radier de Salida (Δ)

Δ (m) = h_2 - H_b = 1,51

7. Pérdida de Carga (Λ)

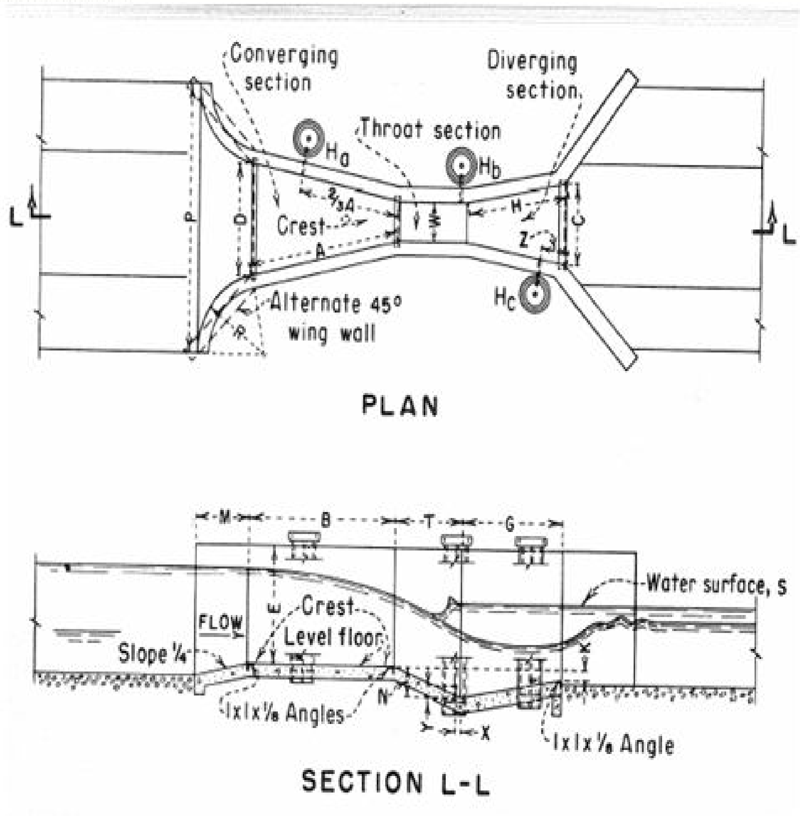
% Sumergencia =	80
Q (cfs) =	529,7
W (ft) =	15,0



De la figura, Λ (ft) = 1,3

Λ (m) = 0,40

9. Geometría



Dimensiones en Planta (m):

A	3,506
2/3A	2,337
B	7,62
C	5,588
D	7,62
G	3,048
T	1,219
X	0,305

Dimensiones en Elevación (m):

E	1,829
K	0,229
N	0,457
Y	0,229

L_{TOTAL} = 11,9

ANNEX B

CALCULATION OF THE GRADUALLY VARYING CHANNEL OF EL YESO WEIR

DATOS:

0,015

i =	0,015	m/m	(PENDIENTE CANAL)
n =	0,015		(RUGOSIDAD)
L_{VERT} =	35	m	(LONGITUD UMBRAL VERTEDERO LATERAL)
L_{CANAL} =	28,4	m	(LONGITUD CANAL CON ANCHO VARIABLE)
Q =	20,77	m^3/s	(CAUDAL DE VERTIDO SIN CONSIDERAR TRAMO UBICADO FRENTE A CAIDA)
q =	0,731	$m^3/s/m$	(CAUDAL UNITARIO)
s =	0,057		($b_X = b_0 + sL_X$; $s = (b_1 - b_0)/L$)
b_0 =	2	m	(ANCHO INICIAL CANAL DE GASTO VARIABLE)
b_1 =	4	m	(ANCHO FINAL CANAL DE GASTO VARIABLE)
$b_{CONTROL}$ =	6,6	m	(ANCHO CAIDA DENTADA)
a =	1	m	(ALTURA GRADA)
Q_{TOTAL} =	25,6	m^3/s	(CAUDAL TOTAL EVACUADO POR VERTEDERO LATERAL)
h_C =	1,154	m	(ALTURA CRITICA INICIO CAIDA)
$h_{CONTROL}$ =	2,154	m	(ALTURA DE CONTROL AGUAS ABAJO)

CALCULOS:

Δb = 0,2 m (INCREMENTO DE ANCHO : CONSIDERA DISCRETIZACIÓN EN 10 TRAMOS)
ΔL = 2,8 m (INCREMENTO DE UMBRAL: CONSIDERA DISCRETIZACIÓN EN 10 TRAMOS)
q^2/g = 0,05

CALCULOS:

Δb = 0,2 m (INCREMENTO DE ANCHO : CONSIDERA DISCRETIZACIÓN EN 10 TRAMOS)
ΔL = 2,8 m (INCREMENTO DE UMBRAL: CONSIDERA DISCRETIZACIÓN EN 10 TRAMOS)
q^2/g = 0,05

	b (m)	h (m)	Ω (m^2)	L (m)	Q (m^3/s)	$V^2/2g$ (m)	B (m)	ΔB (m)	ΔB / ΔL	L / Ω^2 (m^{-1})	$q^2L / g\Omega^2$	$\frac{q^2}{2g}\left(\frac{L_0}{\Omega_0^2}+\frac{L_1}{\Omega_1^2}\right)$
A. ABAJO	4,0	2,15	8,6	28,4	20,8	0,297	2,45	---	---	0,383	0,021	---
↓	3,8	2,22	8,4	25,6	18,7	0,251	2,47	-0,020	-0,0069	0,359	0,020	0,020
	3,6	2,27	8,2	22,7	16,6	0,210	2,48	-0,014	-0,0051	0,339	0,018	0,019
	3,4	2,32	7,9	19,9	14,5	0,173	2,50	-0,012	-0,0041	0,319	0,017	0,018
	3,2	2,37	7,6	17,0	12,5	0,138	2,50	-0,008	-0,0029	0,297	0,016	0,017
	3,0	2,40	7,2	14,2	10,4	0,106	2,51	-0,004	-0,0013	0,273	0,015	0,016
	2,8	2,43	6,8	11,4	8,3	0,076	2,51	0,000	0,0000	0,245	0,013	0,014
	2,6	2,45	6,4	8,5	6,2	0,049	2,50	0,005	0,0019	0,209	0,011	0,012
	2,4	2,47	5,9	5,7	4,2	0,025	2,49	0,013	0,0044	0,162	0,009	0,010
	2,2	2,46	5,4	2,8	2,1	0,008	2,47	0,022	0,0076	0,097	0,005	0,007
A. ARRIBA	2,0											

	b (m)	i - Jm	Ψ (m)	R_H (m)	C	$1/C^2R_H$	J	Jm	i	F.O	h_C (m)	$h > h_C$?
A. ABAJO	4,0	---	8,31	1,04	67,1	0,00021	0,0012	---	---		1,15	
↓	3,8	0,0134	8,24	1,02	66,9	0,00022	0,0011	0,001	0,015	-0,0005	1,35	OK
	3,6	0,0140	8,15	1,00	66,7	0,00022	0,0009	1E-03	0,015	0,0000	1,30	OK
	3,4	0,0138	8,05	0,98	66,5	0,00023	0,0008	9E-04	0,015	-0,0003	1,23	OK
	3,2	0,0139	7,93	0,95	66,2	0,00024	0,0006	7E-04	0,015	-0,0004	1,16	OK
	3,0	0,0143	7,80	0,92	65,8	0,00025	0,0005	6E-04	0,015	-0,0002	1,07	OK
	2,8	0,0142	7,66	0,89	65,4	0,00026	0,0004	5E-04	0,015	-0,0004	0,96	OK
	2,6	0,0143	7,51	0,85	64,9	0,00028	0,0003	3E-04	0,015	-0,0004	0,84	OK
	2,4	0,0145	7,33	0,81	64,3	0,00030	0,0001	2E-04	0,015	-0,0003	0,67	OK
	2,2	0,0147	7,12	0,76	63,7	0,00032	0,0000	1E-04	0,015	-0,0002	0,45	OK
	2,0											

Gener

an AES Company

ALTO MAIPO HYDROELECTRIC PROJECT

BASIC ENGINEERING

CONTRACT AM-CO304

HYDRAULIC CALCULATION REPORT
DISCHARGE WORKS TO MAIPO RIVER -

630-CI-MCA-005 i

0	03-12-08	BIDDING	AU	RC	EW	RB / AL	PAW	CMD
ISSUANCE	DATE	PURPOSE OF THE ISSUANCE	PREPARED BY	REVIEWED BY	GENERAL COORDINATOR'S APPROVAL	D. PROJECT / D. ATTACHMENT APPROVED BY	ENGINEERING ASSISTANT DIRECTOR'S APPROVAL	PROJECT MANAGER'S APPROVAL
AMEC - Cade amec POCH Ingeniería Norconsult NORPLAN							REVIEW 0	
							N°: 630-CI-MCA-005	

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Presidente Errázuriz 3943   Phone (562) 207 2622 FAX (562) 263 5152 Santiago CHILE

1. INTRODUCTION

Project Alto Maipo considers the construction of two run of river plants, which means that during its normal operation they will not alter the hydrologic regime of Maipo river, downstream from the discharge area of Las Lajas power station. Nevertheless, the runoff regime of the flow could be affected during special operations of the power stations, such as load intakes or load rejections.

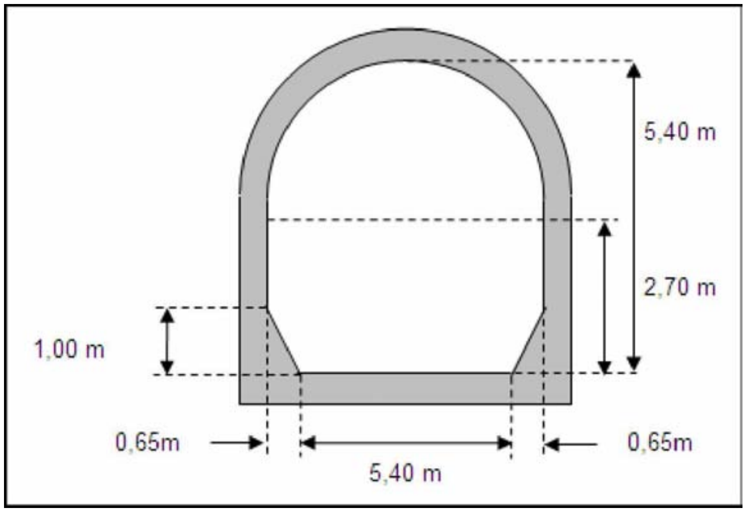
To minimize these possible impacts, there has been a compensation volume arranged in the surge chamber of Las Lajas power station of 300,000 (m^3) and of a similar regulation volume in the discharge tunnel, which makes it necessary for this tunnel to operate under pressure at a certain length of its development.

Given the characteristics of the Las Lajas discharge tunnel, the accumulation of the 300,000 (m3) is achieved in a stretch of about 9,200 (m), measured upstream from the outlet works. The possibility of carrying out a regulated delivery to Maipo river is obtained with works that include slide gates in the discharge area of the river.

Due to the slope of the tunnel, the accumulated volume of 300,000 (m^3), produces a piezometric level of 17 (m) immediately upstream from the slide gate structure in relation to the invert of the outlet works of the tunnel. The discharge works to Maipo river, as it is detailed in layouts 630-CI-PLA-051 and 630-CI-PLA-052, have been designed in the exposed rocks at the exit area of the tunnel and it is made up by two 5 (m) height slide gates and 3.50 (m) of width, both separated by a space of 1,20 (m). The discharge tunnel is connected to a reinforced concrete domed duct, shown in Figure 1 that gets to the aforementioned slide gates. Immediately upstream from the slide gates structure a chimney has been emplaced, also made of reinforced concrete, with a square section of 8mX8m that ends in a weir that pours the excess flow to the rock mass in the right bank of Maipo river. These works avoid an improper operation of the slide gates that could involve a tunnel length under pressure that may affect the turbine of the power station.

The slide gates of the area have their supporting area and rotation axis at 5.50 (m) height over the invert of the horizontal exit channel and thus, the radius of the area would be R=7.5 (m). The slide gates of the area will be equipped with flat gates upstream that have the ability to close against runoff and shutter weirs downstream that allow isolating each area in case it is necessary. The slide gates of the area will be activated through an oleohydraulic mechanism that allows a fine regulation. The pressure duct, upstream from the structure of the gates, shows a curve in plant of R=15 (m) to the axis, with an angle of the center of £* = 68 From the beginning of the curve and upstream, there will be a straight stretch of the box of reinforced concrete, with an estimated length of 200 (m) measured from the extremity of the entrance of the discharge tunnel. The dimensions of this duct are shown in Figure 1.

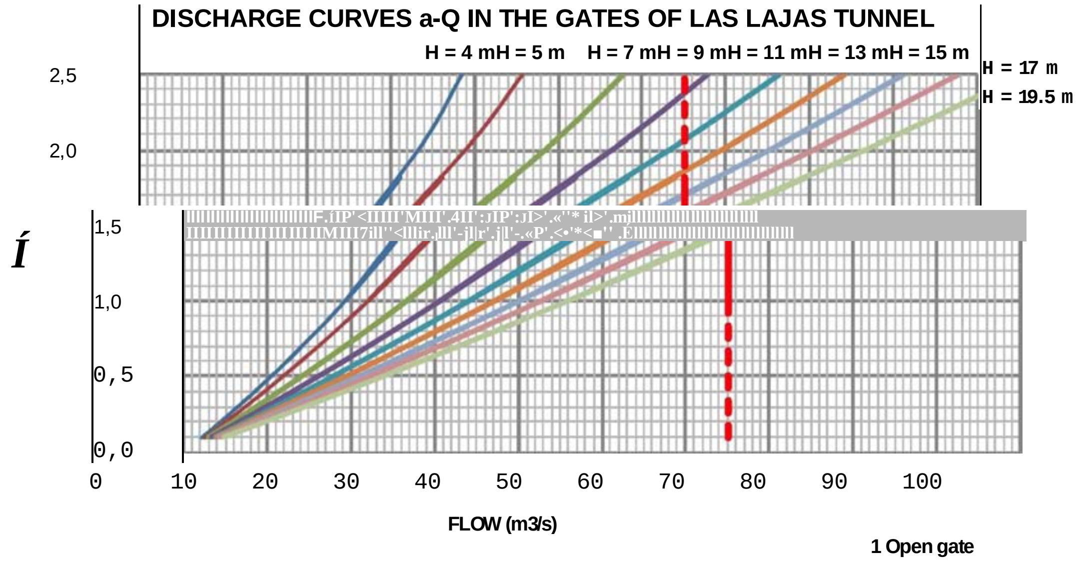
Figure 1. Concrete Duct at the end of the Las Lajas Discharge Tunnel

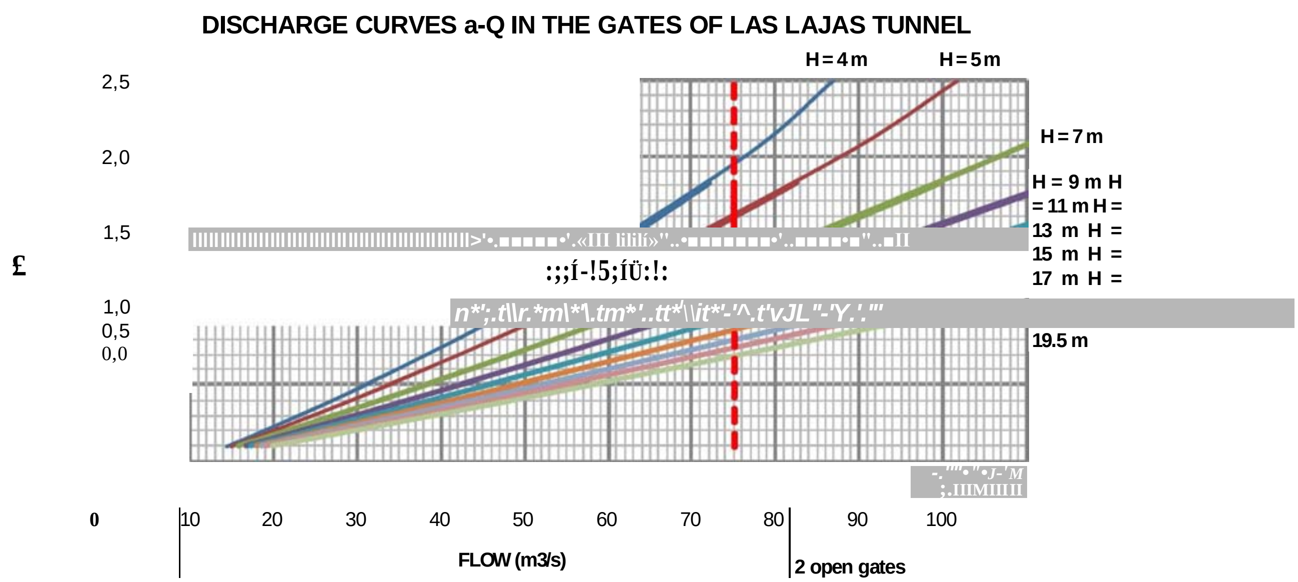


2. DISCHARGE CURVE OF THE STRUCTURE

The discharge works have two 3.5 m wide radial gates, through which the evacuated flow should be controlled, and which is done by opening the gates given the level of water in the weir tower. Due to this, it is necessary to obtain curve sets Opening – Flows, that allow to determine the evacuated flow for a certain opening (m) knowing the height H (m) (measured from the invert.) Figure 2 shows these curve sets for cases 1 and 2 of opened gates.

Figure 2

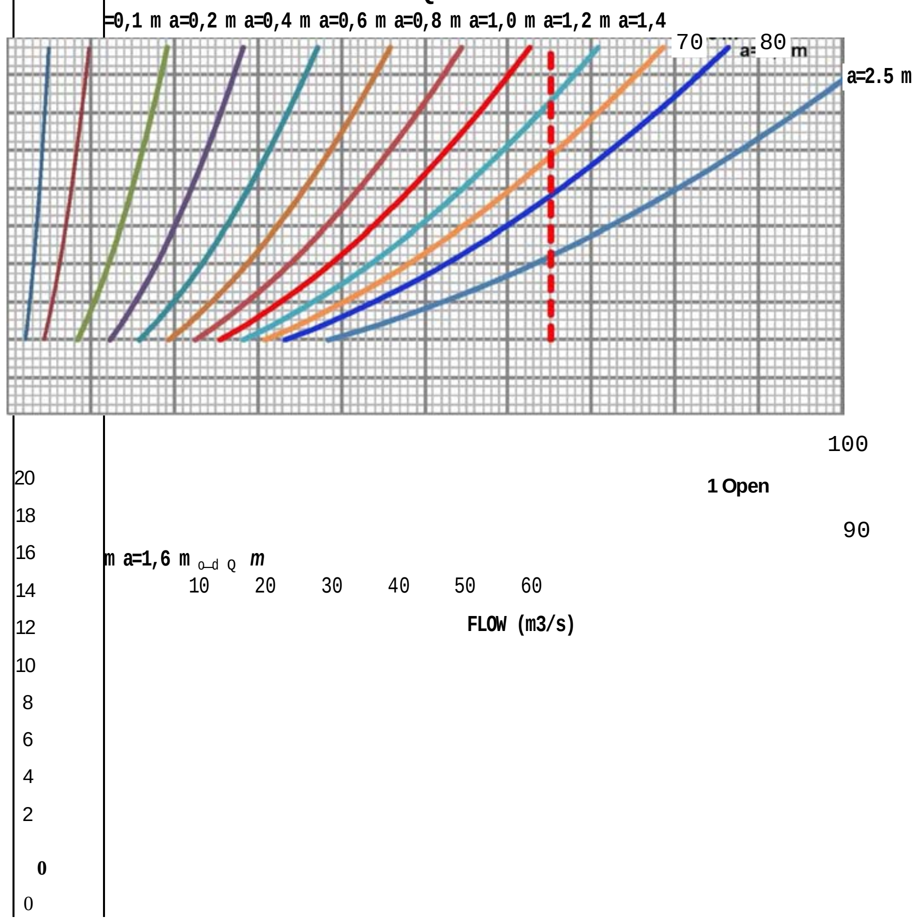




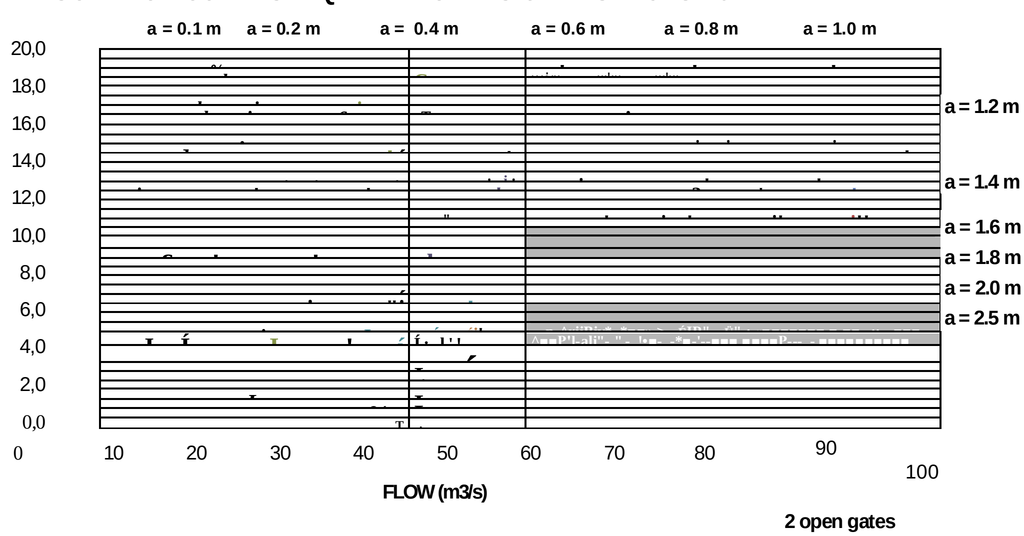
Also, Figure 3 presents H- Q curves that allow estimating the Q flow (m3/s), for a given H (m) value and with a known gate opening at (m).

Figure 3.

DISCHARGE CURVES H-Q IN THE GATES OF LAS LAJAS TUNNEL



DISCHARGE CURVES H-Q IN THE GATES OF LAS LAJAS TUNNEL



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3. ENERGY DISSIPATOR

To have a safe runoff delivery in the outlet works of the discharge tunnel under special operation conditions, it has been decided to have an energy dissipator at the end of the discharge tunnel. According to the project of the discharge tunnel, the outlet threshold of the energy dissipator would be at an altitude of 817 (m.a.s.l.).

The design of the energy dissipator is conditioned by the operation of Las Lajas power plant at its maximum capacity. In this operation, with the gates of the area controlling the flow with the maximum load of H = 17 (m), the outlet rate of the water mass under the areas is extremely high. This energy dissipator will allow providing a runoff with a similar rate to that of Maipo river.

The flow considered for designing the energy dissipator is 65 (m^3/s). This value corresponds to the design flow of the tunnel. A simple stilling basin has been selected and it consists of a rectangular chamber with a gradient of slope descent 4/1 (H/V) and with a 2.5 (m) height and a upper gradient of vertical parameter of the same height to exit threshold on its end downstream. In the determination of the height of the rise gradient, at the end of the stilling basin, the theory exposed by Swiss researchers W.H. Hager and R. Sinniger in an article published in 1985 in the "Journal of Hydraulic Research." The length of the stilling basin has been calculated according to the recommendation of Francisco Javier Domínguez, regarding the gradients precedent with torrent and the proposed by Foster and Skrinde (Ven Te Chow, Chapter 15).

The shape of these works can be seen in Figure 4. The chamber of the stilling basin has been assumed as excavated in the rock, with the bottom and part of the lateral walls, with the surfaces and roughness of the rock (of very good quality), it has a width of 8.20 (m), a length of 33 (m) and a height of lateral walls of 7.3 (m).

With the flow of 65 (m3/s) and a specific energy (Bernoulli) of H = 17 (m), both gates should have an opening of a = 0.75 (m) (m). The contraction coefficient of the plate under the gates is C_C = 0.69 (according to Henderson) with which the runoff rate of the torrent at the outlet of the gates is v_0 = 17.97 (m/s). Keeping the Bernoulli, the height of the torrent at the beginning of the stilling tank will be of h_1 = 0.41 (m) and the rate of v_0 = 19.33 (m/s). (The Froude N° of the torrent is F = 9.64). According to Hager and Sinniger, the gradient height downstream S required to confine the protrusion in the tray, is obtained verifying the following relationship of the Froude Nº:

$$F = Yx(Y + 2AY + 2A - 1)\ 2(F-1)$$

Being **F**= 3 y A = . The denominations can be seen in
A A
Figure 2. The calculation shows that a downstream gradient height of S = 2.5 (m) is required.

The protrusion length according to Foster and Skrinde, is:

$$L_R = 5 \cdot (h_3 + s) = 21{,}80\ \boldsymbol{(ni)}$$

To determine the total length of the stilling basin, the distance that arises with the drop of the stream from the gate area was calculated, and for this the abacus proposed in Figure 159 of the third edition of "Hydraulics" of F.J. Domínguez, for the gradients preceded by torrent. The distance was estimated in 11 (m), due to which the stilling basin was projected with 33 (m) in total, including the slope descent gradient of 4/1 (H/V).

To determine the height of the lateral walls of the stilling tank, a height of h2 = 5.46 (m) has been determined. Admitting a compensation of 1/3 of this height, the walls of the stilling basin must be at least of H_m = 7.30 (m).

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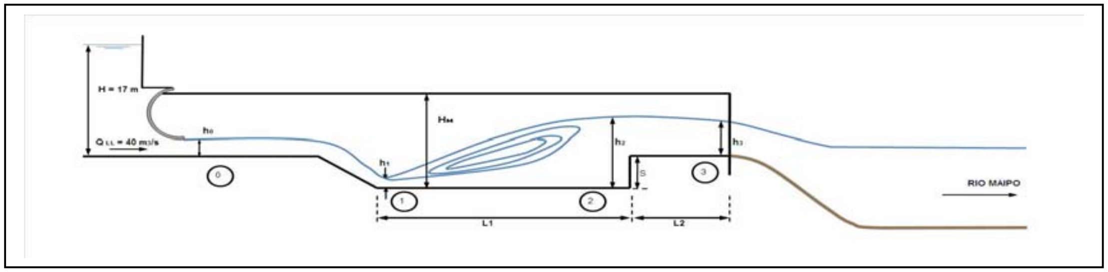
Figure 4. Diagram of the Stilling Basin of the Discharge of Maipo River



Section 0. Corresponds to the contracted vein : h0 = CC•a

Section 1. Beginning of the stilling basin

Section 2. End of the stilling basin

Section 3. Discharge to Maipo river: h3 = hcritical

4. VERIFICATION OF THE UNREGULATED DISCHARGE WORKS

Finally, the behavior of the discharge works was analyzed for a situation of maximum flow, without the regulation of the gates. For this condition, Q = 65 m^3/s and $h_3 = h_{critical}$ = 1.86 (m). Figure 5 shows a diagram of this situation, where the runoff in the concrete duct that connects the discharge tunnel to the projected regulation works is considered.

According to the calculations, it has been determined that for this situation of operation in the works, section (01) will experience crisis ($h_{01} = h_c$); the previous means that the river imposed by the gradient of section (3) does not condition the type of runoff in (01); in turn, the crisis of this section does not manage to impose a supercritical runoff in section (1), therefore, between these two sections a very undulated runoff should take place, very close to the crisis. Upstream from section (01) there should be a depressed river in a soft slope, that finally imposes a height of the river in section (02) with a value very close to the normal height of the domed section that considers the design of the discharge tunnel of Las Lajas, whose value is of approximately 4.10 (m).

According to the nomenclature of Figure 5, the results obtained are the following:

Section	3	2	1	0	01	02(a. below)	02(a. above)
Height (m)	1.86	5.46	5.46	1.54	2.64	3.27	3.93
v (m/s)	4.23	1.45	1.45	6.05	4.78	3.90	2.60

As in this case, in the stilling basin there is not a hydraulic jump, the compensation can be estimated with the expression:

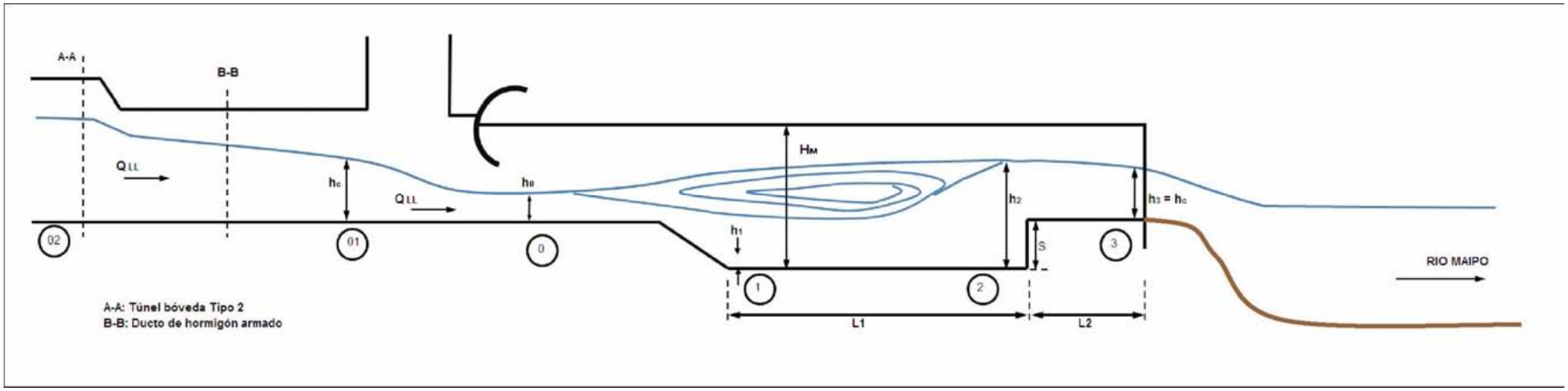
$$r = 0.30 + \frac{v_2^{\,2}}{2g} = 0.41(m)$$

Thus, for this condition, the wall height would be H_m = 5.87 (m).

Therefore, based on the calculations carried out, the following has been adopted by the stilling basin: H_m = 7.3 (m) and $L_{GRADENT}$ = 10 (m), $L_1 = L_R$ = 23 (m), L_2 = 3.5 (m) y S = 2.5 (m).

Figure 5. Diagram of the Stilling Basin of the Discharge of Maipo River

Section 02.	Corresponds to the end of the vault and the beginning of the concrete duct
Section 01.	Corresponds to the end of the concrete duct
Section 0.	Corresponds to the section of the gates



Section 1.	Beginning of the stilling basin
Section 2.	End of the stilling basin
Section 3.	Discharge to Maipo River: $h_3 = h_{critical}$

In regards to the design of this stilling basin, it is important to take into account that its design flow is of 65 (m^3/s), due to which it is not recommendable for it to exceed this value. Therefore, in the regulated operation of these works this condition should be taken into account, thus a value of load H, upstream from the gates should not exceed the value of an opening limit, that is to say at $\leq a_{LIM}$, so that $Q \leq 65$ (m^3/s) . Figures 6 and 7 attached, show limit opening curves, for the cases of one and two opened gates, which should be considered in the regulated operation of the discharge tunnel of Las Lajas power station.

Figure 6

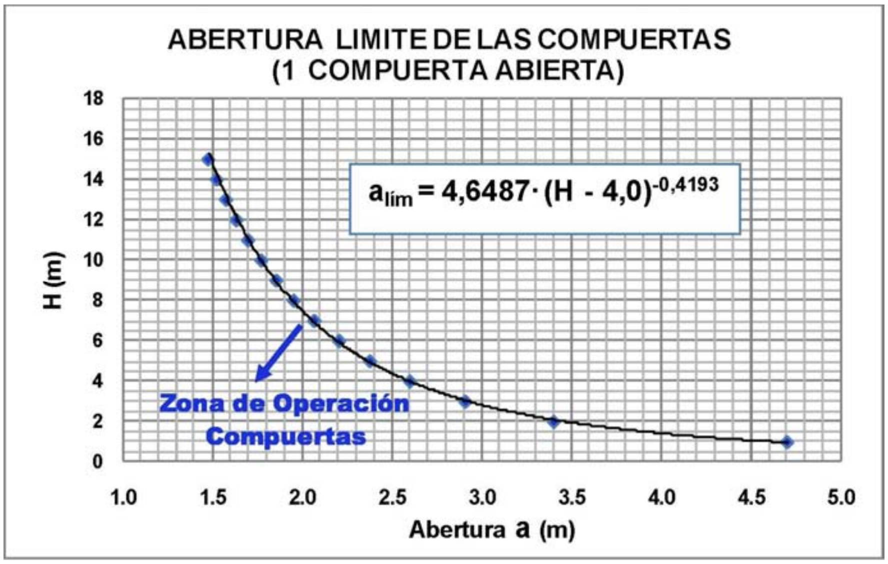
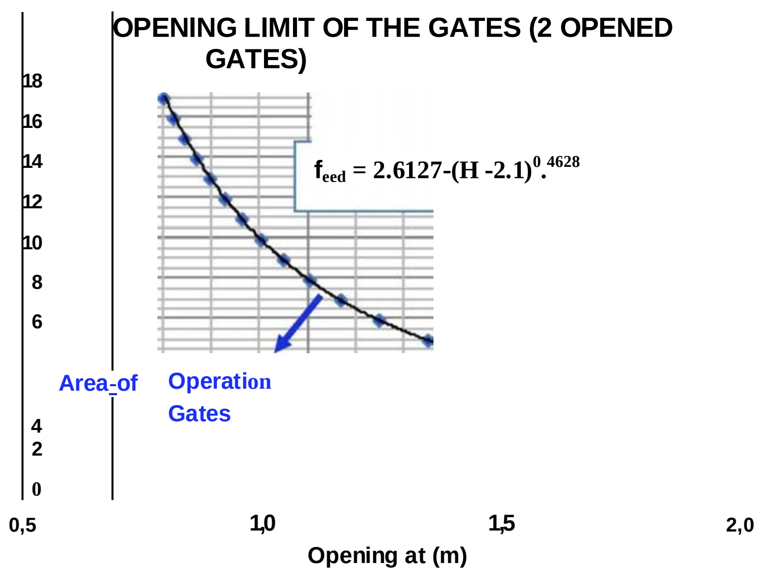


Figure 7



5. SAFETY WEIR

According to what was mentioned, there is a chimney or tower, of reinforced concrete with a square section of 8mx8m, emplaced upstream from the gates, with a weir in its upper area, that pours the excess flow to the rock mass located to a side of the right bank of the Maipo river. This weir is an emergency structure that allows to provide safety to the system given an improper operation of the gates, that could eventually compromise a length of the tunnel under pressure, that could affect the turbines of the power station; the operation of this weir would give time for the protection systems of the power station to operate properly in case it is needed, during an emergency situation.

The weir has a length of 8 (m), with which its hv load can be calculated with the equation:

$$Q = mLh_v\sqrt{2gh_v}$$

Where:

Q	=	Flow (m^3/s)
L	=	Length of the weir (8m)
h_v	=	Load over the threshold of the weir
m	=	Expense coefficient = 0.40
g	=	Gravity acceleration (9.8 m/s^2)

With these numbers, for the maximum operation of the power station (65 m^3/s) the load would have a maximum value equal to 2.76 (m). Due to this, the walls of the chimney were projected up to a height of 3 (m) above the threshold of the weir.

6. WORKING DESIGNS

Based on this information, these discharge works were projected, whose details and shapes are shown in Designs 630-CI-PLA-051 and 630-CI-PLA-052 of the Alto Maipo Project.

PERMIT	**Permit for regularization and defense works of natural channels**	
REGULATION	EIAS Regulation	Article 106
	Sectorial of Reference	Article 171 of Statutory Decree Nº 1.122, Water Code
AUTHORITY	General Directorate of Water	
WORK	**EL YESO COLLECTION**	

Conditions for granting and technical and formal contents necessary to prove compliance

a) ***The submission of a sketch of general location.***
See Figure 1.1 of document 020-HI-INF-012 of EIA Annex 8.

b) ***The submission of a floor layout of the modified area, comprising at least one hundred meters (100 m) before and one hundred meters (100 m) after of the modified area.***
See Figure 3.3.1 of document 020-HI-INF-012 of EIA Annex 8.
See layout 020-CI-PLA-028 of EIA Annex 1.

c) ***The submission of a longitudinal profile of all the tranche above mentioned.***
See Figure 4.1.1 of document 020-HI-INF-012 of EIA Annex 8.

d) ***The submission of a transversal profile of the typical section and the critical section of the waterway to be modified.***
See Figures 4.1.2 and 4.2.2 of document 020-HI-INF-012 of EIA Annex 8.

e) ***The submission of a transversal profile of the typical section and the critical section of the waterway projected.***
See layout 020-CI-PLA-020 of EIA Annex 8.
See document 610-CI-MCA-005 of this Annex.

f) ***The indication of engineering structures, if any, in the tranche to be modified.***
In the tranche where water intake will be located, there are no engineering structures.

g) ***The description of the planned works;***
Please refer to document 610-CI-MCA-005 of this Annex.

h) ***And technical specification report containing the necessary hydraulic calculations, including, at least, the calculation of maximum capacity of the waterway without modification and the calculation of maximum capacity of the waterway modified.***
Please refer to document 610-CI-MCA-005 of this Annex.

PERMIT	**Permit for regularization and defense works of natural channels**	
REGULATION	EIAS Regulation	Article 106
	Sectorial of Reference	Article 171 of Statutory Decree Nº 1.122, Water Code
AUTHORITY	General Directorate of Water	
WORK	**COLORADO RIVER DISCHARGE**	

Conditions for granting and technical and formal contents necessary to prove compliance

a) ***The submission of a sketch of general location.***
See Figure 1.1 of document 020-HI-INF-008 of EIA Annex 8.

b) ***The submission of a floor layout of the modified area, comprising at least one hundred meters (100 m) before and one hundred meters (100 m) after of the modified area.***
See Figure 3.3.1 of document 020-HI-INF-008 of EIA Annex 8.
See layout 020-CI-PLA-028 of EIA Annex 8.

c) ***The submission of a longitudinal profile of all the tranche above mentioned.***
See Figure 4.1.1 of document 020-HI-INF-008 of EIA Annex 8.

d) ***The submission of a transversal profile of the typical section and the critical section of the waterway to be modified.***
See Appendix 2 of this Annex.

e) ***The submission of a transversal profile of the typical section and the critical section of the waterway projected.***
See layout 020-CI-PLA-044 of EIA Annex 8.
See layout 020-CI-PLA-039 of EIA Annex 1.
See Figures 4.1.2 and 4.1.3 of document 020-HI-INF-008 of EIA Annex 8.

f) ***The indication of engineering structures, if any, in the tranche to be modified.***
In the tranche, there are no engineering structures.

g) ***The description of the planned works;***
Please refer to pages 1 and 2 of document 020-HI-INF-008 of EIA Annex 8.

h) ***And technical specification report containing the necessary hydraulic calculations, including, at least, the calculation of maximum capacity of the waterway without modification and the calculation of maximum capacity of the waterway modified.***
Please refer to document 020-HI-INF-008 of EIA Annex 8.
Please refer to document 610-CI-MCA-005 included in this Annex.

PERMIT	Permit for regularization and defense works of natural channels	
REGULATION	EIAS Regulation	Article 106
	Sectorial of Reference	Article 171 of Statutory Decree Nº 1.122, Water Code
AUTHORITY	General Directorate of Water	
WORK	MAIPO RIVER DISCHARGE	

Conditions for granting and technical and formal contents necessary to prove compliance

a) ***The submission of a sketch of general location.***
See Figure 1.1 of document 020-HI-EST-001 of EIA Annex 8.

b) ***The submission of a floor layout of the modified area, comprising at least one hundred meters (100 m) before and one hundred meters (100 m) after of the modified area.***
See Figure 4 of document 020-HI-EST-001 of EIA Annex 8.

c) ***The submission of a longitudinal profile of all the tranche above mentioned.***
See Figure 6 of document 020-HI-EST-001 of EIA Annex 8.

d) ***The submission of a transversal profile of the typical section and the critical section of the waterway to be modified.***
See Figures of Annexes 1 and 2 of document 020-HI-EST-001 of EIA Annex 8.

e) ***The submission of a transversal profile of the typical section and the critical section of the waterway projected.***
See layout 630-CI-PLA-049 of EIA Annex 8.
See layouts 630-CI-PLA-051 and 52 of this Annex.

f) ***The indication of engineering structures, if any, in the tranche to be modified.***
In the tranche, there are no engineering structures.

g) ***The description of the planned works;***
Please refer to documents 630-CI-MCA-005 and 022 that are included in this Annex.

h) ***And technical specification report containing the necessary hydraulic calculations, including, at least, the calculation of maximum capacity of the waterway without modification and the calculation of maximum capacity of the waterway modified.***
Please refer to documents 630-CI-MCA- 005 and 022 that are included in this Annex.

PERMIT	**Permit for regularization and defense works of natural channels**	
REGULATION	EIAS Regulation	Article 106
	Sectorial of Reference	Article 171 of Statutory Decree Nº 1.122, Water Code
AUTHORITY	General Directorate of Water	
WORK	**RECTIFICATION OF COLORADO RIVER WATERWAY**	

Conditions for granting and technical and formal contents necessary to prove compliance

a) The submission of a sketch of general location.
See Figure 1.1 of document 020-HI-INF-008 of EIA Annex 8.

b) The submission of a floor layout of the modified area, comprising at least one hundred meters (100 m) before and one hundred meters (100 m) after of the modified area.
See Figure 3.3.1 of document 020-HI-INF-008 of EIA Annex 8.

c) The submission of a longitudinal profile of all the tranche above mentioned.
See Figure 4.1.1 of document 020-HI-INF-008 of EIA Annex 8.

d) The submission of a transversal profile of the typical section and the critical section of the waterway to be modified.
See Appendix 2 of this Annex.

e) The submission of a transversal profile of the typical section and the critical section of the waterway projected.
See layout 020-CA-PLA-044 of EIA Annex 8.
See layout 020-CI-PLA-039 of EIA Annex 1.
See Figures 4.1.2 and 4.1.3 of document 020-HI-INF-008 of EIA Annex 8.

f) The indication of engineering structures, if any, in the tranche to be modified.
In the tranche, there are no engineering structures.

g) The description of the planned works;
Please refer to pages 1 and 2 of document 020-HI-INF-008 of EIA Annex 8.

h) And technical specification report containing the necessary hydraulic calculations, including, at least, the calculation of maximum capacity of the waterway without modification and the calculation of maximum capacity of the waterway modified.
Please refer to document 020-HI-INF-008 of EIA Annex 8
Please refer to document 610-CI-MCA-005 that is included in this Annex.

PERMIT	**Permit for regularization and defense works of natural channels**	
REGULATION	EIAS Regulation	Article 106
	Sectorial of Reference	Article 171 of Statutory Decree Nº 1.122, Water Code
AUTHORITY	General Directorate of Water	
WORK	**COLORADO RIVER BRIDGE**	

Conditions for granting and technical and formal contents necessary to prove compliance

a) The submission of a sketch of general location.
See Figure 1.1 of document 020-HI-INF-013 of EIA Annex 8.

b) The submission of a floor layout of the modified area, comprising at least one hundred meters (100 m) before and one hundred meters (100 m) after of the modified area.
See Figure 3.3.1 of document 020-HI-INF-013 of EIA Annex 8.

c) The submission of a longitudinal profile of all the tranche above mentioned.
See Figure 4.1.1 of document 020-HI-INF-013 of EIA Annex 8.

d) The submission of a transversal profile of the typical section and the critical section of the waterway to be modified.
See Figures 4.1.2 to 4.1.5 of document 020-HI-INF-013 of EIA Annex 8.

e) The submission of a transversal profile of the typical section and the critical section of the waterway projected.
See layout 020-CA-PLA-028 of EIA Annex 8.
Idem letter d), there is no waterway modification

f) The indication of engineering structures, if any, in the tranche to be modified.
In the tranche, there are no engineering structures.

g) The description of the planned works;
Please refer to documents 020-HI-INF-013 of EIA Annex 8.

h) And technical specification report containing the necessary hydraulic calculations, including, at least, the calculation of maximum capacity of the waterway without modification and the calculation of maximum capacity of the waterway modified.
It is not applicable, see documents 020-HI-INF-013, and page 17 “Conclusions” in EIA Annex 8.

PERMIT	**Permit for regularization and defense works of natural channels**	
REGULATION	EIAS Regulation	Article 106
	Sectorial of Reference	Article 171 of Statutory Decree Nº 1.122, Water Code
AUTHORITY	General Directorate of Water	
WORK	**EL YESO BRIDGE**	

Conditions for granting and technical and formal contents necessary to prove compliance

a) The submission of a sketch of general location.
See Figure 1.1 of document 020-HI-INF-015 of EIA Annex 8.

b) The submission of a floor layout of the modified area, comprising at least one hundred meters (100 m) before and one hundred meters (100 m) after of the modified area.
See Figure 3.3.1 of document 020-HI-INF-015 of EIA Annex 8.

c) The submission of a longitudinal profile of all the tranche above mentioned.
See Figure 4.1.1 of document 020-HI-INF-015 of EIA Annex 8.

d) The submission of a transversal profile of the typical section and the critical section of the waterway to be modified.
See Figures 4.1.2 to 4.1.5 of document 020-HI-INF-015 of EIA Annex 8.

e) The submission of a transversal profile of the typical section and the critical section of the waterway projected.
See layout 020-CA-PLA-026 of EIA Annex 8.
Idem letter d), there is no waterway modification

f) The indication of engineering structures, if any, in the tranche to be modified.
In the tranche, there are no engineering structures.

g) The description of the planned works;
Please refer to documents 020-HI-INF-015 of EIA Annex 8.

h) And technical specification report containing the necessary hydraulic calculations, including, at least, the calculation of maximum capacity of the waterway without modification and the calculation of maximum capacity of the waterway modified.
It is not applicable, see documents 020-HI-INF-015, and page 17 “Conclusions” in EIA Annex 8.

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COLORADO RIVER
LAS LAJAS POWER STATION FOREBAY TRANCHE

TRANSVERSAL PROFILES AND
HYDRAULIC AXIS LEVELS FOR T = 100 YEARS

(SUPPLEMENTARY DOCUMENT TO REPORT 020-HI-INF-008)

INTRODUCTION

To protect the collection works, located on both banks of Colorado River, a rectification of this waterway has been projected, in a tranche of about 800 m. The rectified waterway would be a channel of trapezoidal section of 40 m. wide with slopes 2:1 (H: V), which would be protected by consolidated rockfill dams. Figure 1 shows a plant view of the area, covering a length of 2,200 m downstream from Alfalfal I bridge.

In this tranche the hydraulic axel has been calculated, with a flow of T = 100 year return period for the current situation and the situation with rectification project of the waterway in the area indicated in Figure 1. To carry out the above, 25 transverse profiles were taken, on the basis of a transported laser survey; the location in plant of these profiles are shown in Figure 1.

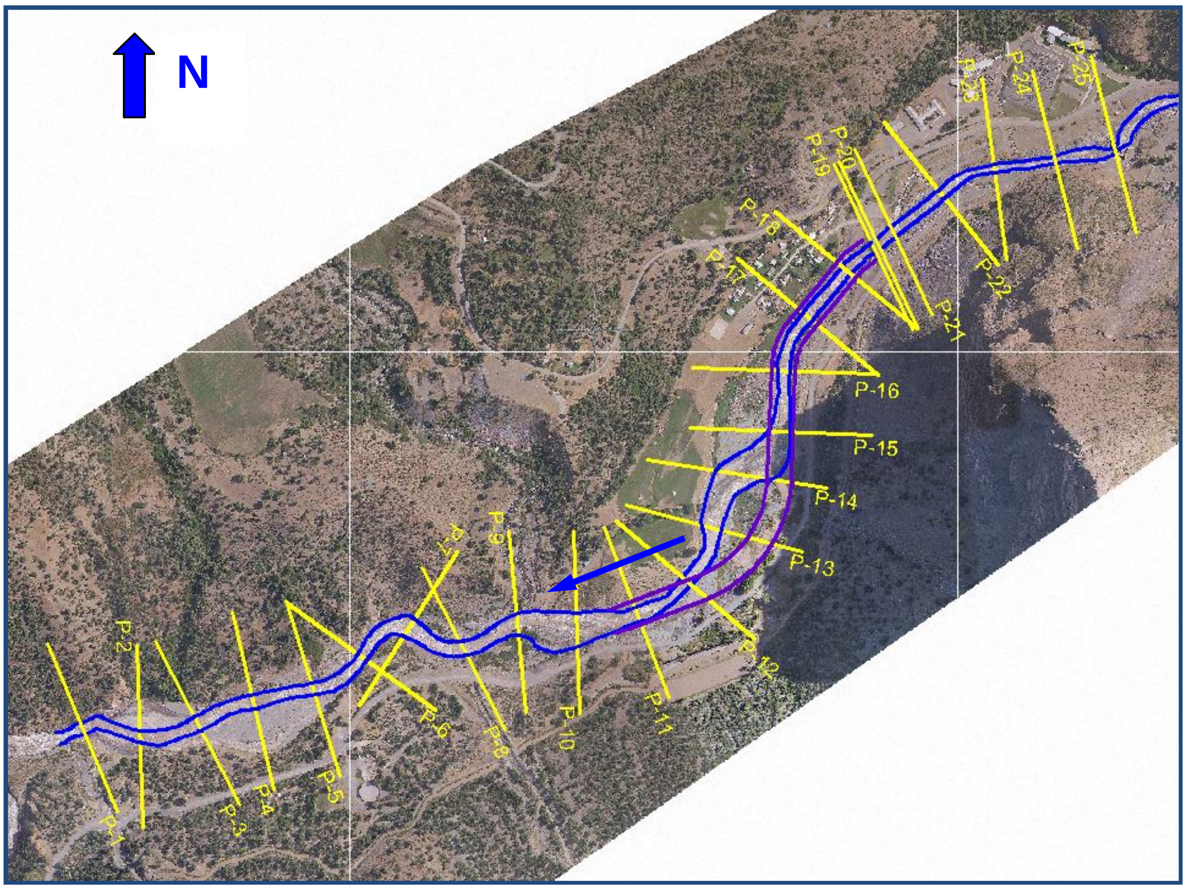


Figure 1. Colorado River Plant with Location of Transversal Profiles

FLOOD FLOWS

According to hydrological studies performed, the maximum flows in Maitenes water intake area are:

Table 1

Flood Flows

T (Years)	Colorado in Maitenes WI. Caudal (m^3/s)
2	190
5	310
10	410
25	580
50	740
100	930

ESTIMATED HYDRAULIC AXES

For a return period T = 100 years, the following results in the tranche under study are obtained:

3.1 Longitudinal Profiles

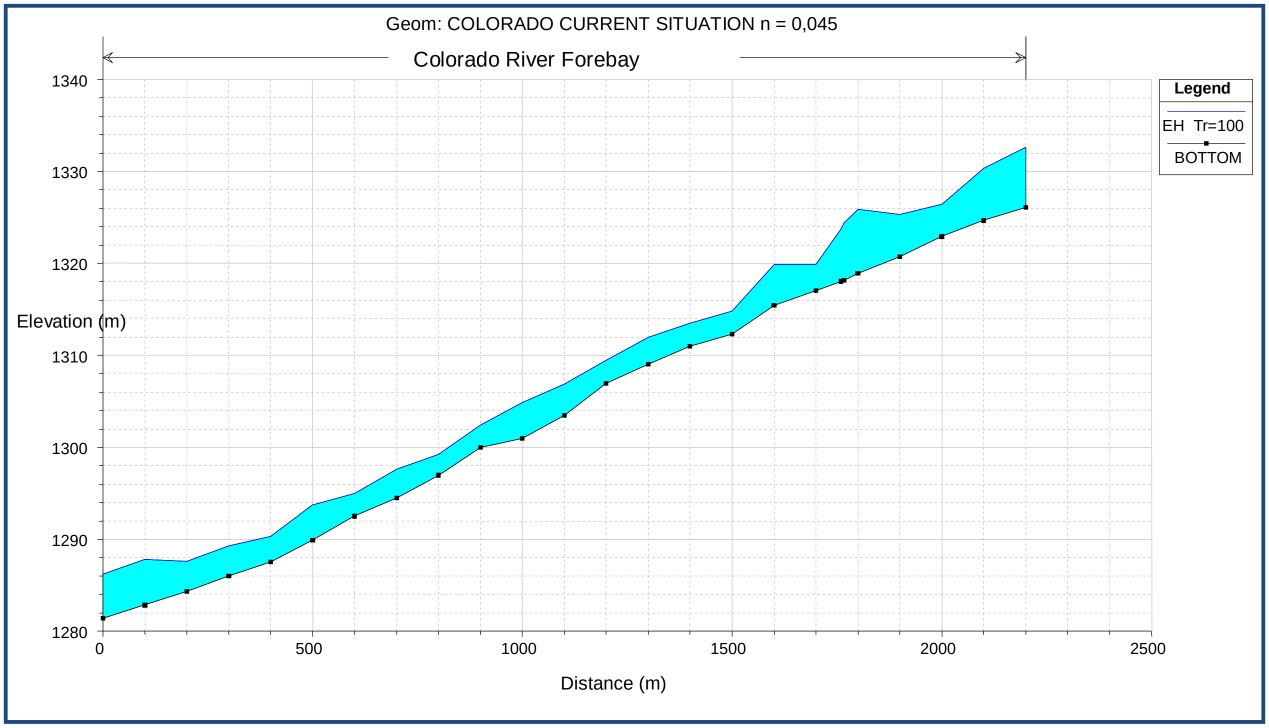


Figure 2

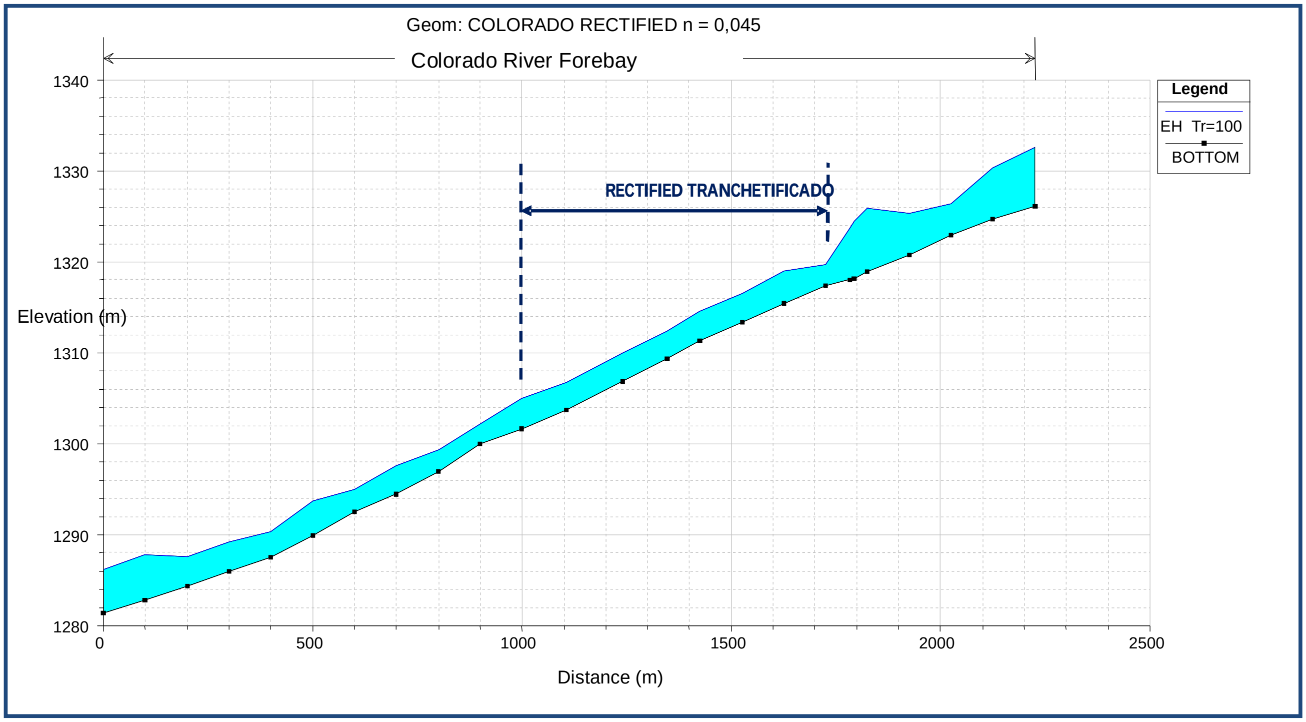


Figure 3

3.2 Transversal Profiles Rectified Tranche

- Current Situation (without rectification)

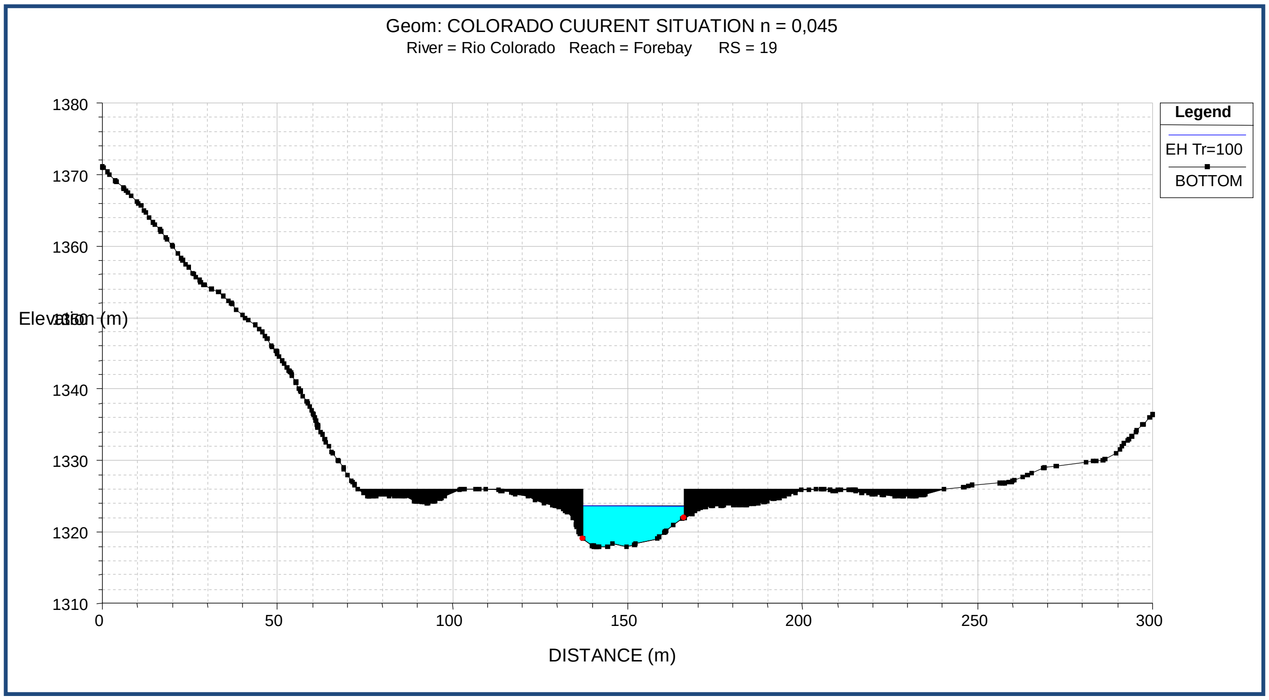


Figure 4. Alfalfal I Bridge

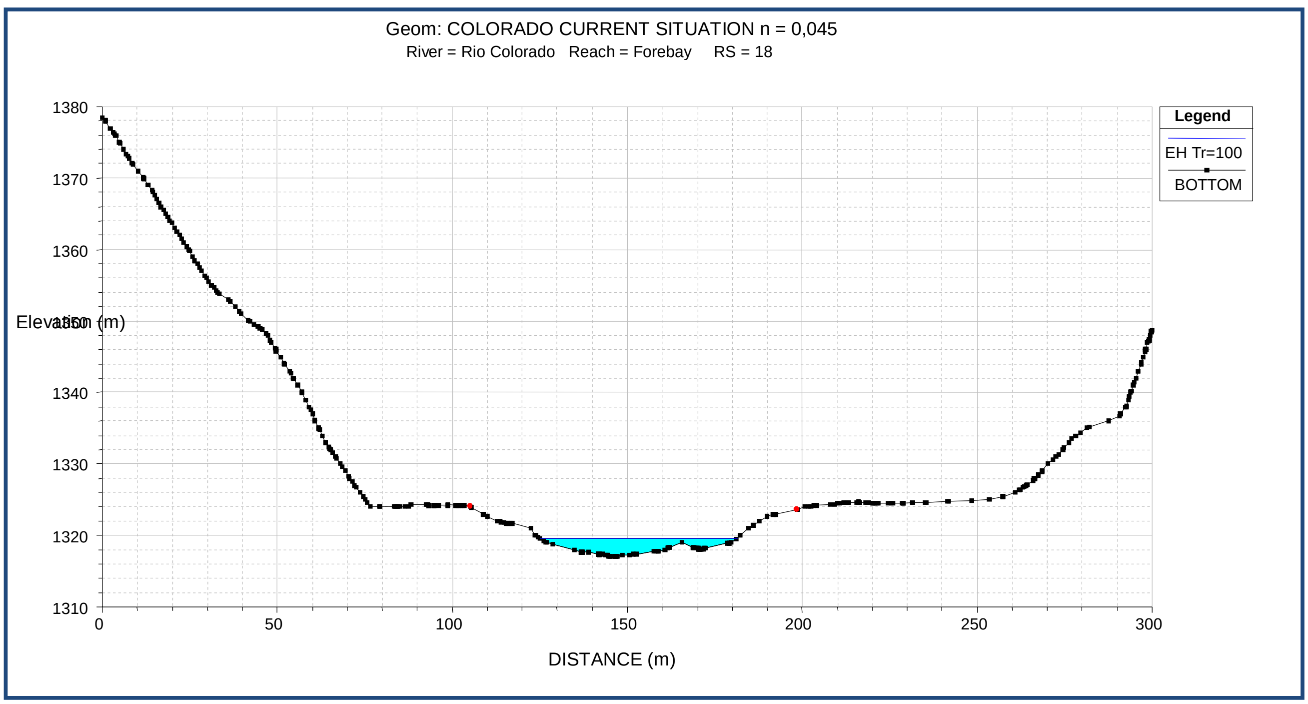


Figure 5

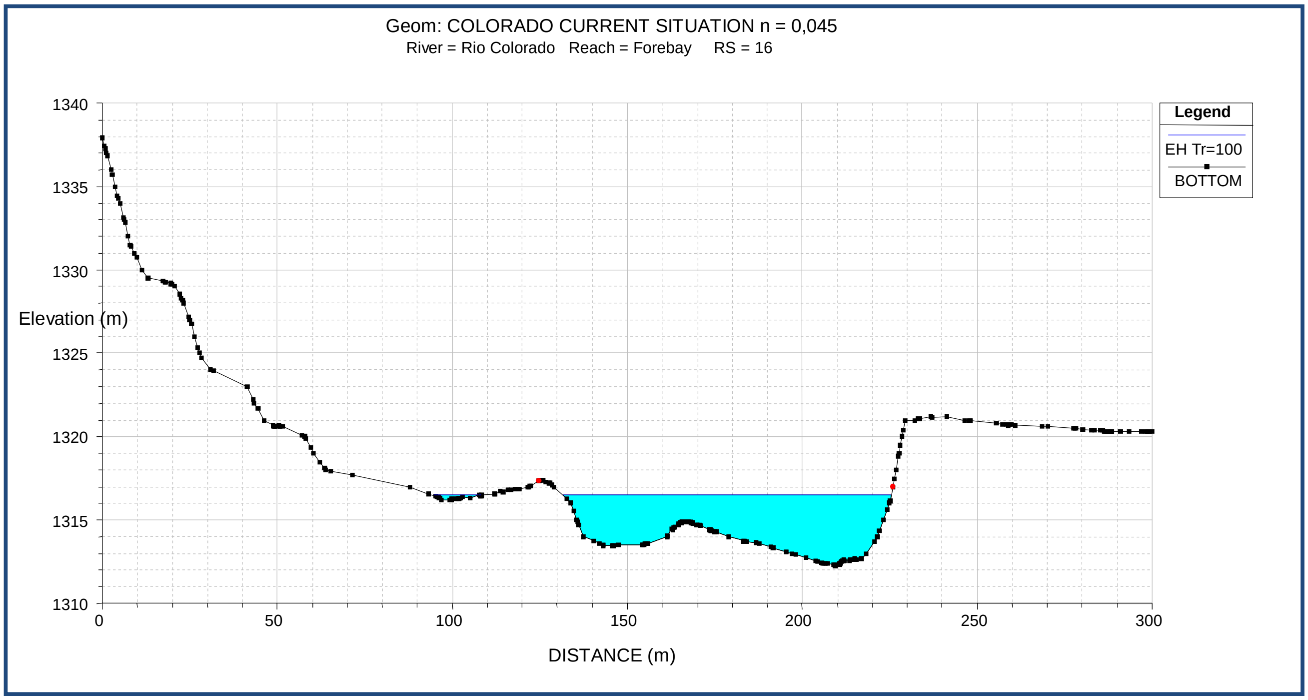


Figure 6

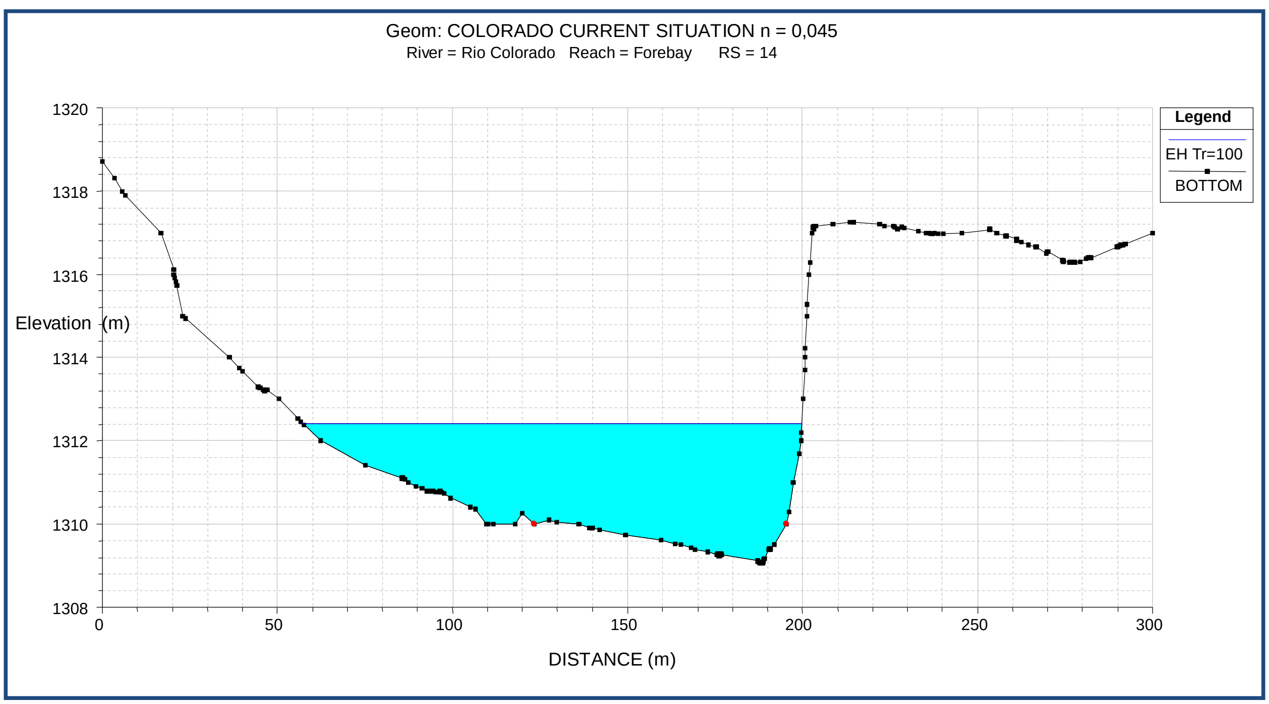


Figure 7

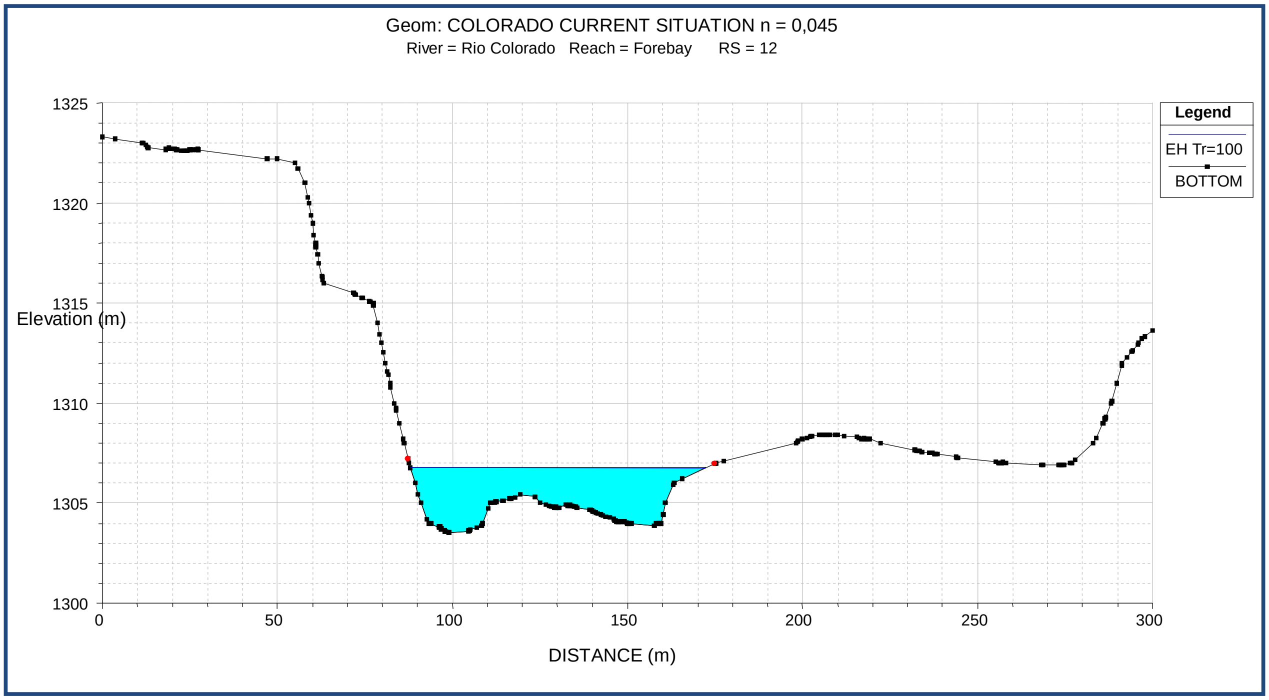


Figure 8

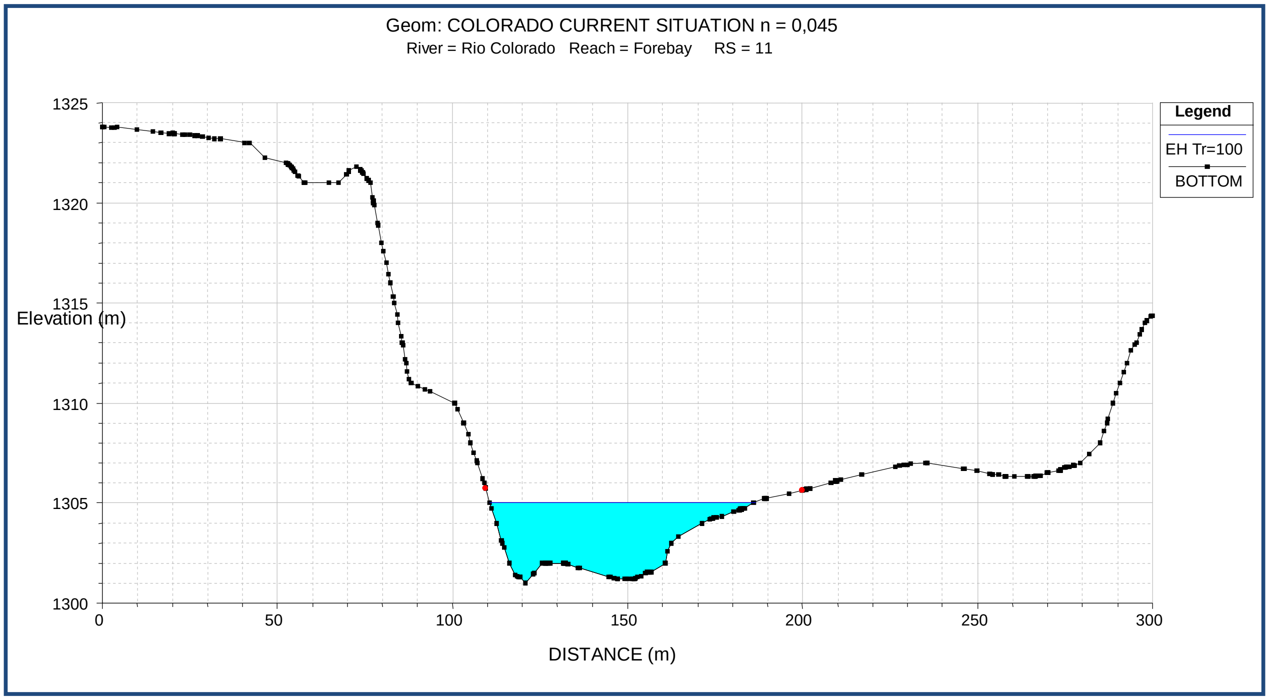


Figure 9

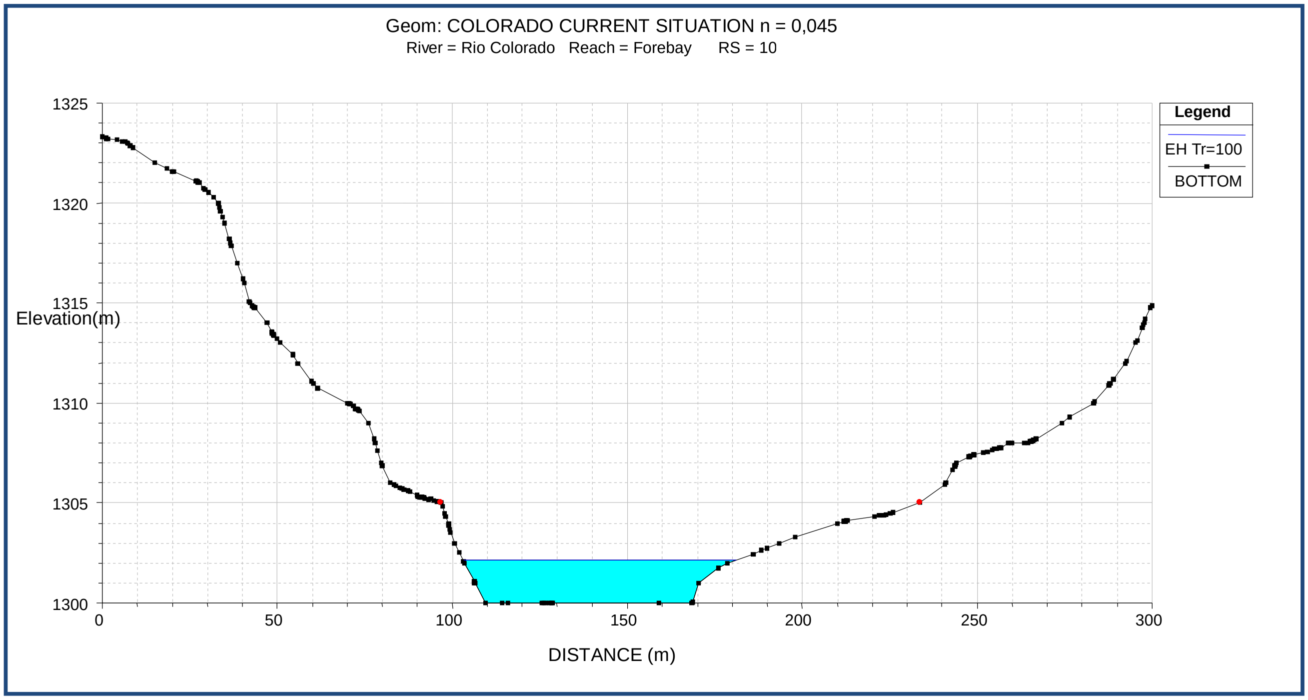

Geom: COLORADO CURRENT SITUATION n = 0,045
River = Rio Colorado Reach = Forebay RS = 10
Legend
EH Tr=100
BOTTOM
Elevation(m)
1325
1320
1315
1310
1305
1300
0
50
100
150
200
250
300
DISTANCE (m)

Figure 10

- Future Situation (with rectification)

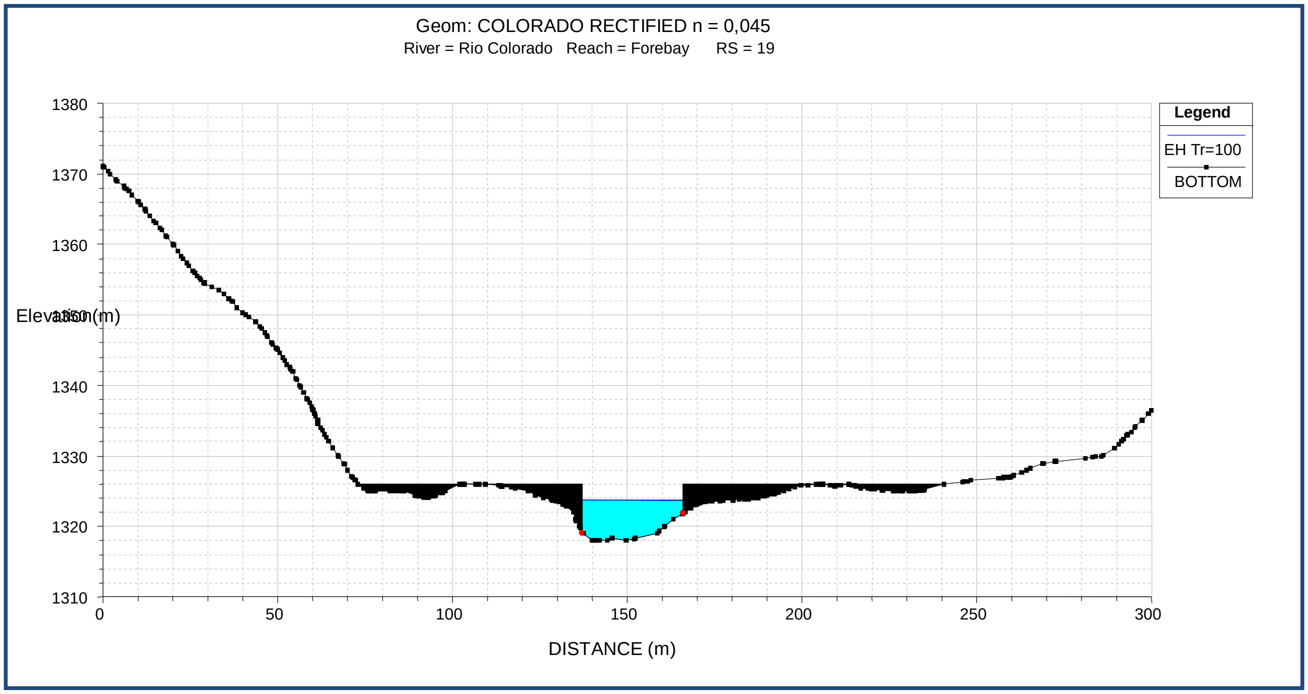


Figure 11. Alfalfal I Bridge

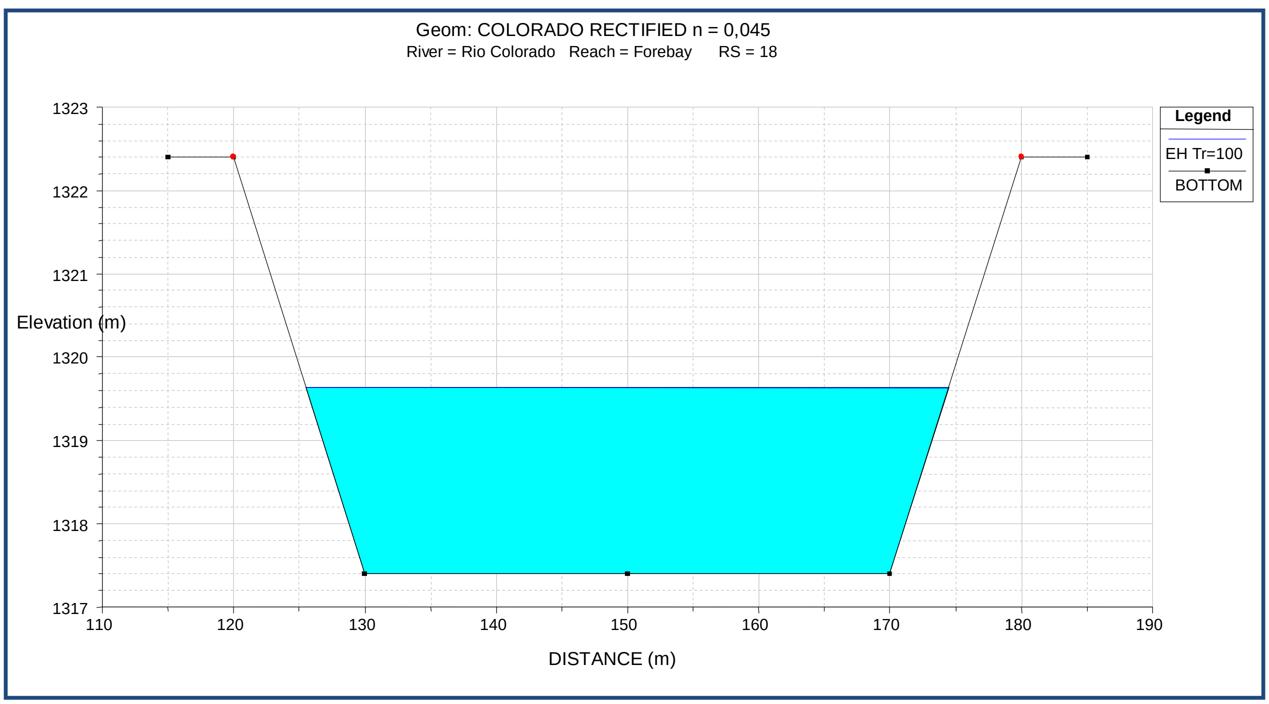


Figure 12

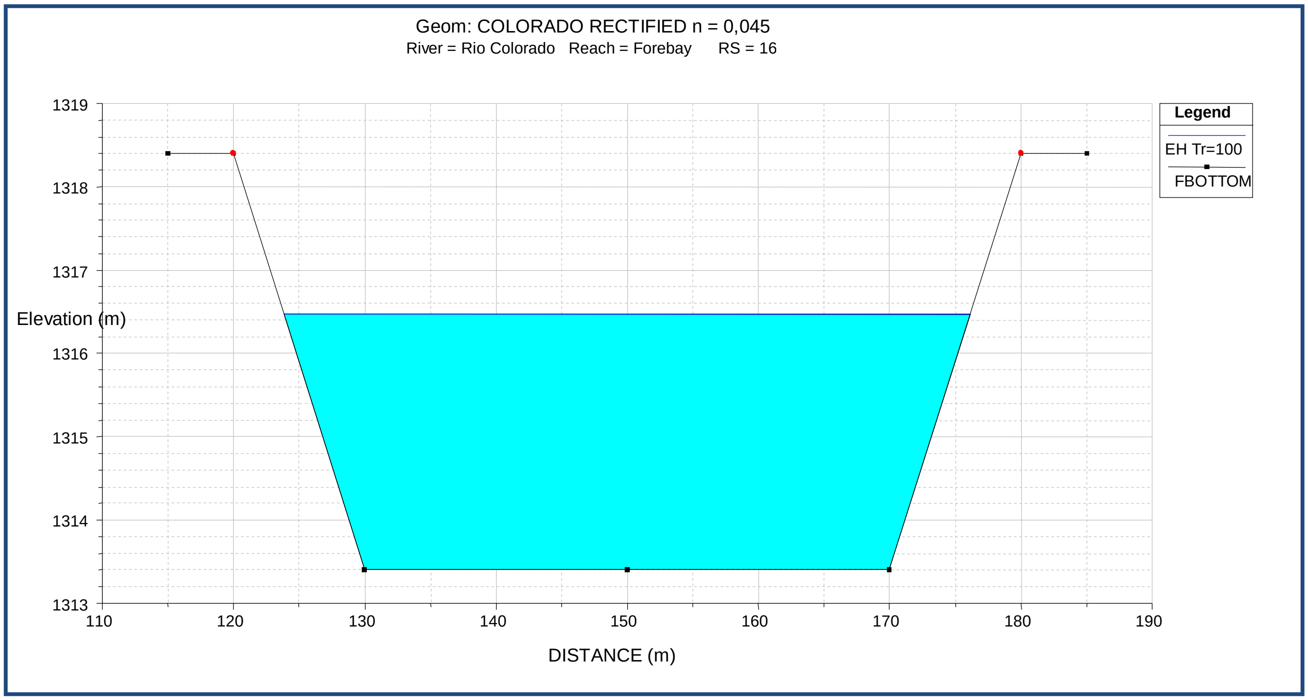


Figure 13

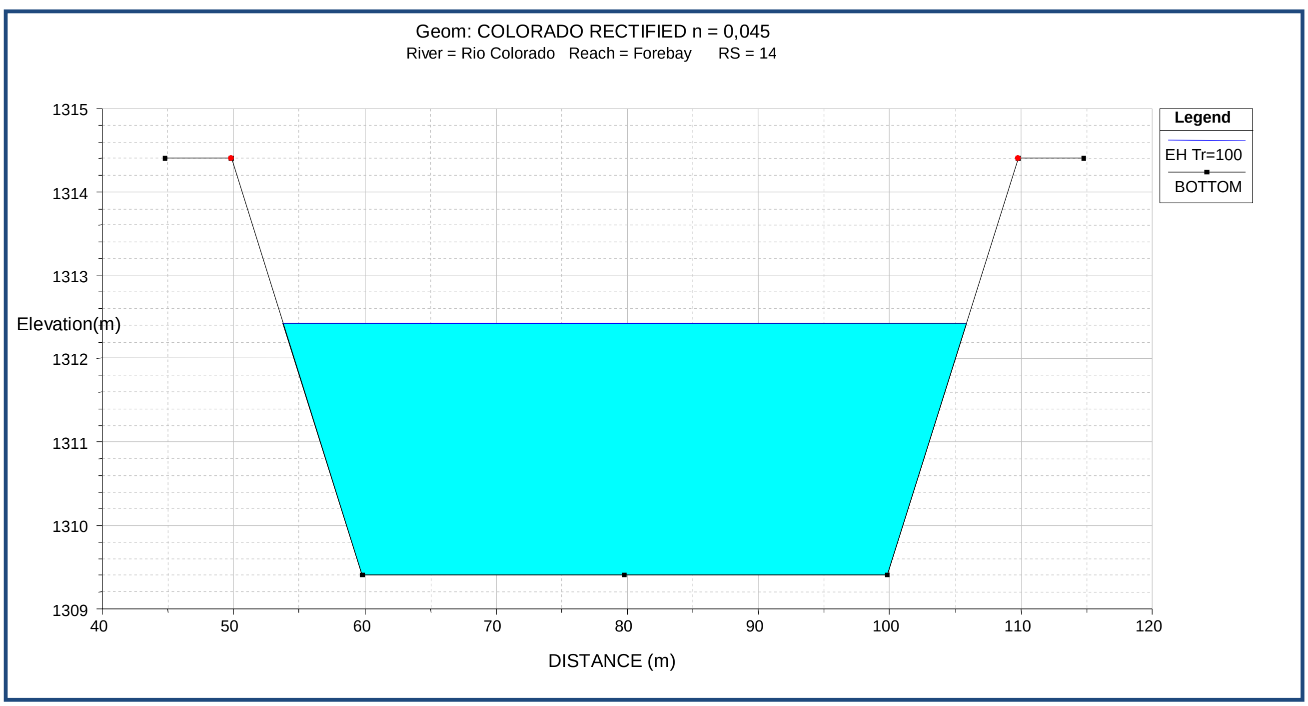
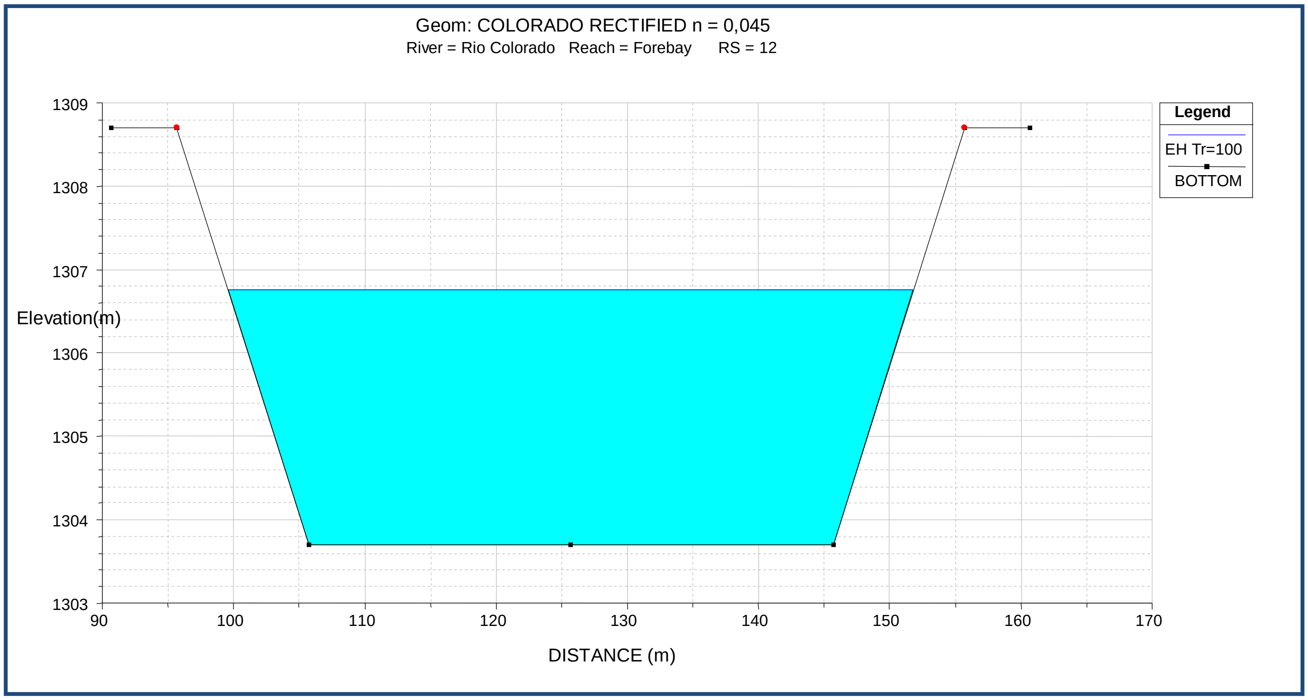


Figure 14



Geom: COLORADO RECTIFIED n = 0,045
River = Rio Colorado   Reach = Forebay   RS = 12
Legend
EH Tr=100
BOTTOM
Elevation(m)
1309
1308
1307
1306
1305
1304
1303
90
100
110
120
130
140
150
160
170
DISTANCE (m)

Figure 15

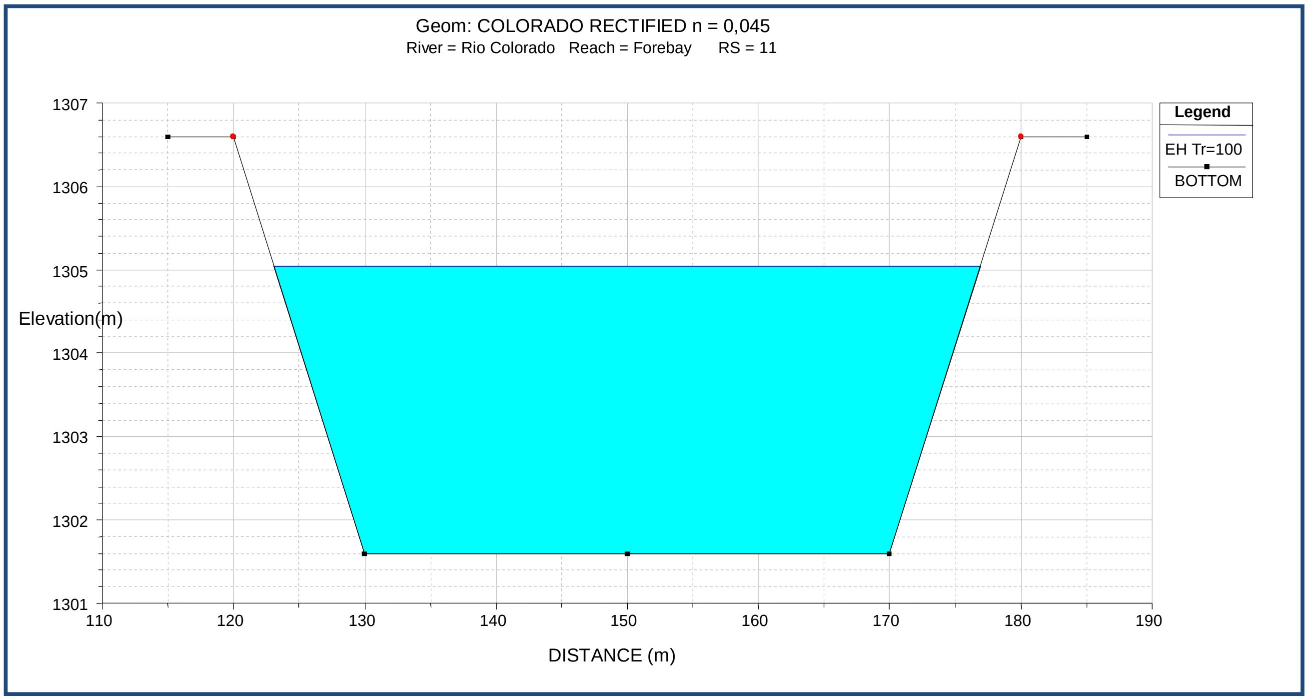


Figure 16

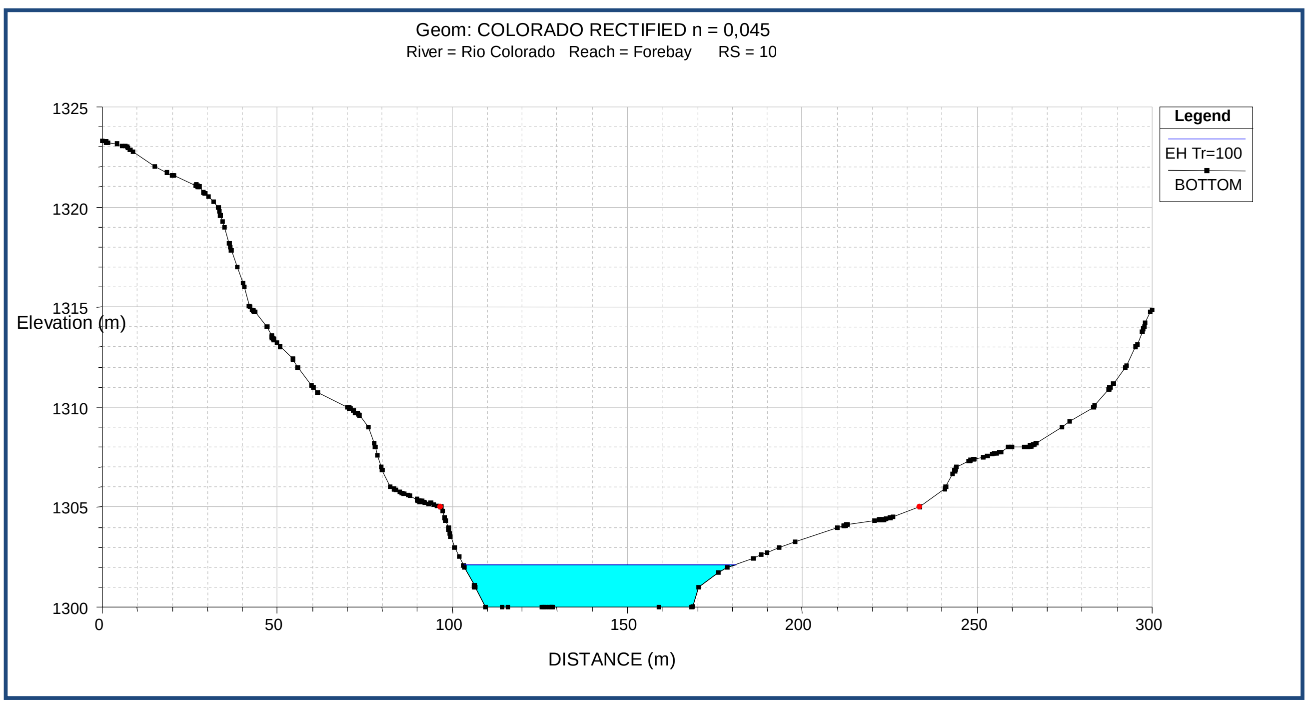


Figure 17